Rugged Machine Vision

Advanced Digital Machine Vision Cameras

illunis

Operations Manual

Release 2/12/2013

CAMERA Link

Welcome to the RMV users manual. Our goal is to provide the best possible documentation for the RMV cameras and we will update this document with your feedback. We welcome comments and criticism of this document.

This document covers the CCD versions of the RMV digital cameras. A separate document will cover the CMOS versions of the RMV.

Please direct your comments to:
EMAIL: info@illunis.com

Special Notes

Rugged Machine Vision

Specifications subject to change without notice.

About illunis:

Illunis is a privately held LLC located in beautiful Minnetonka Minnesota, USA. Since it's inception in 2000 illunis has grown into a technological innovator in the digital camera arena. We value our customers and suppliers and offer state of the art products at the industries most competitive prices. As a self funded company, illunis is a stable, reliable source for demanding OEM's who include the most prestigious names in the world. We invite you to visit us and together we can create a prosperous future.

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RMV Release Notes

Thank you for purchasing the RMV digital camera from illunis. The RMV camera uses the latest technology including the camera link (CL) and Gigabit Ethernet standards with the following features:

RMV Release operational notes

- CCD sensors with one or two taps are supported.
- CCD sensors from Truesense Imaging: KAI-1010, KAI-2020, KAI-4021, KAI-04022, KAI-08050, KAI-11002, KAI-16000, KAI-16050, KAI-16070, KAI-29050 are supported in color and monochrome.
- Sensor data is sampled at 14bits giving a maximum dynamic range of 72dB
- Data is processed as 12 bit data and output as camera link data in 8,10, or 12 bits
- Digital data is tap reordered (TRO), corrected for bad pixels (PDM), and a lookup table (LUT) is applied.
- Image data can be overlaid with text, line plots and column plots.
- Image data is measured with specialized detectors for brightness, sharpness, tap matching, noise, raster size and exposure time. These detectors can be read as raw data or as processed into appropriate scientific values.
- Image exposure can be in free run and external triggered modes.
- Image data can be read as a partial scan (PS) on sensors that support the function.
- Image processing of DGO, PDM, LUT, PS can be enabled independently in free run mode and trigger mode.
- Analog processing includes gain, offset and dark current compensation.
- Analog gain is fixed at the factory and a digital gain is provided for the user Digital gain (DGO) is from zero to 16 times and is performed in 12 bit resolution.
- Analog and digital gain is performed independently for each sensor tap.
- Functions are provided for common control of gains and offsets.
- Data is output in the industry standard camera link format.
- Camera communication initializes at 9600 baud and can be increased to 115,200 baud.
- Image data is read as either active pixels or as all pixels in an over scan mode.
- Sensor dark current correction is performed with an automatic line or frame clamp.
- A STROBE output signal is available for applications that require a electronic signal indicating actual exposure of the sensor.
- A look up table (LUT) is provided at 12 bits resolution equal to the full dynamic range of the data path.
- The camera is communicated with in data packets that are error checked.
- The camera has a temperature sensor that is placed at the hottest part of the camera.
- The camera is set in modes and has five registers that indicate the current mode set.
- The camera has two registers that indicate operational status.
- The camera state can be saved to EEPROM and restored on power up.
- The camera state can be save to or loaded from a file.
- The camera state, as it left the factory, is saved by illunis and can be sent via email,
- A graphical user interface (GUI) is provided for convenient control of the camera functions. This program is visual basic based and source code is available.

RMV Document Revisions

RMV release new features

Support for 14Bit Analog Front End (AFE)

Newest release ADC hardware supported for exceptional low noise performance.

Histogram Equalization (HEQ)

Camera can auto equalize images based on histogram min/max measurements. This function utilizes the Master DGO to apply offset and gain.

Mechanical IRIS control + AE with IRIS

A PWD servo controller is provided to drive a mechanical IRIS using a RC Servo. AE is integrated with the IRIS to provide min/max/step/reverse/start functions.

Histogram AE coefficients

AE is supported with histogram bin calculations with coefficient multipliers

Long V-count

This mode supports FRM imaging with frames longer than normal thus supporting custom/slower frame rates.

Master-Slave mode

This mode supports master-slave configurations of cameras where the master camera runs AE, IRIS and HEQ functions and transmits this data to the slave cameras. This allows for large arrays of cameras to be configured and operated as a single imager. Data is framed and error checked.

Histogram OSD Plot

The RMV incorporates a 512 point histogram that can be viewed on screen.

Master Digital Gain and Offset

An additional digital gain and offset circuit is provided for the HEQ functions.

Frame Counter Reset Added

Writing to the frame counter detector resets all frame counters to zero.

Option Board Support

The new option board is supported with mechanical shutter drive, orientation sensors, optically isolated strobe and pickle switch, servo drive and fan control.

Triggered Double Exposure System with Mechanical Shutter

Special modes for the mechanical shutter to stop exposure on the second frame of the TDE mode. Shutter delay is programmable.

Trigger arming function

Trigger can be “armed” to prevent accidental use. Disarm is provided.

Bug Fixes

AE is supported in FRS mode.
Vertical Binning bug fixed
Notch removed from histogram OSLP
Active Pix counter works in Histo OSLP mode
DGO changed to offset then gain = DOG

GigE Support

The GigE versions of the RMV are supported in this release. Our RMV GigE cameras use the Pleora interface. Please consult www.pleora.com for their latest manual.

Special Notes

The RMV cameras utilize different circuit cards than the VMV and XMV cameras. In most cases an older camera can be upgraded to a RMV camera.

Older Document Revisions

GigE Support

The GigE versions of the RMV are supported in this release.

Multi User EEPROM locations

The RMV now supports up to 4 EEPROM user configurations in addition to the standard user and factory locations. This is useful for saving multiple states of the camera. The user states are restored by copying the EEPROM locations into the main user memory and restarting the camera. Please refer to the "RMV AppNote EEPROM User States.pdf" for more details.

LUT and FFC tables are now stored in EEPROM

The Look Up Tables (LUT) and Flat Field Correction (FFC) can now be stored in EEPROM and restored with a simple command sequence. A new set of commands that changes the LUT and FFC load functionality are included.

Boot-loader support

The RMV microprocessor code can be updated with a boot-loader. The FPGA code must be reprogrammed at the factory.

Gamma LUT command

The Gamma LUT command loads a gamma table based on the command data where the data = gamma * 100. Thus loading a gamma LUT with decimal 45 will create a LUT with the gamma factor of 0.45

TPD Resolution

The resolution of the Transfer Pulse Delay (TPD) are supported. Previously the TPD time unit was fixed at 64 pixel clock periods. The new functionality supports TPD time periods of 4, 16, 64, and 1024 pixel clocks. This provides for very fine resolution for short exposures and also very long exposures.

Data On Screen Display (DOSD) Function

The DSOD function inserts a line of digital data into the top 8 bits of the video image. This data is inserted at the line after the last normal line of image data. The data is displayed by increasing the FVAL stop line by one. The data can be user determined, predefined camera parameters or both. Refer to the app note "RMV Data Overlay.pdf".

Vertical Binning X32

The RMV camera now supports vertical binning by 32x.

LED Flashes on frame start

The flashing of the heartbeat LED has been changed to flash on the beginning of a frame transfer. The LED is reset by the main loop of the micro processor and may change with operation/function load.

Micro Processor Boot-loader

The microprocessor used in the RMV can now be reprogrammed through the camera link port. The GUI program supports a "firmware loader" dialog.

Very short trigger times now supported

Trigger times shorter than the photodiode setup and transfer time are now supported. Use the **SetTriggerTime** function. Note that though the FPGA can execute very short exposure timing, the analog response of the drive circuits and the sensor may not.

Camera now tracks min and max environment (temp)

The camera tracks the minimum and maximum operating temperature in the camera EEPROM. The data is saved between restarts. This is very useful for tracking environmental data. The min/max temp values are reset when a "copy user to factory" command is issued

Horizontal Binning Averaging

In previous versions the horizontally binned data was summed. In the E8.2 firmware a feature for averaging the HBIN data by 1, 2, 4, or 8. The data is clipped to full scale (4095).

Automatic Tap Matcher (ATM)

An auto tap matcher is provided. If a color sensor is used then the color mode must be activated for the ATM to work correctly. The ATM is useful for many applications but not all, please read the manual carefully before using.

Serial baud rate stored in EEPROM

The camera link serial baud rate can be stored in EEPROM. Warning as this can cause the camera communication with your application to fail

SetTime functions and Auto Exposure work in PS mode

The SetTime functions for triggered and free run modes now support partial scan mode (PS). The SetTime functions will work in either PS mode or Binning mode but not both at the same time. As a side effect the AE mode which calls the SetTime functions will work in these modes.

Sub revisions for FPGA and Microprocessor

The camera now includes commands for major and minor (SUB) revisions. SUBVERSIONS are minor revisions that encompass bug fixes. Major revisions include new features.

PxGA color change

The PxGA Colors have changed from the previous versions
The GNU on screen display now works in all cameras.

Additional Information

Additional information is available for advanced features of the RMV cameras. They are available as pdf files and include:

Advanced Auto Exposure

This application note describes the advanced AE modes including the mechanical IRIS control, Histogram Equalization, Master-Slave modes, and Histogram based AE calculations.

Advanced Timing

This application note describes the advanced trigger timing of the RMV cameras. The advanced timing includes multiple TPD resolutions, timing diagrams and equations, and special states for flash strobe imaging. These features are available only for firmware revisions E7 and above.

Data On Screen Overlay

This application note describes the support for the Data overlay function added to the rev E7 FPGA. The Data overlay or DOSD functions allow for the insertion of binary data into the video image. The data is inserted outside the normal active video area.

EEPROM User States

This application note describes the multi USER EEPROM state mechanism in the RMV cameras. Up to 4 USER states are available for storing customize camera parameters. These features are available only for firmware revisions E7 and above.

Boot loader Information

This application note describes the use of the firmware boot loader. The boot loader is available for all firmware revisions and must be installed at the factory.

Custom Configuration files

This application note describes how to create a custom configuration file for loading multiple cameras to the same user state without affecting the factory tuning parameters. This application note is relevant to all camera revisions.

Please contact info@illunis.com

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Chapters:

Chapter 1: Overview

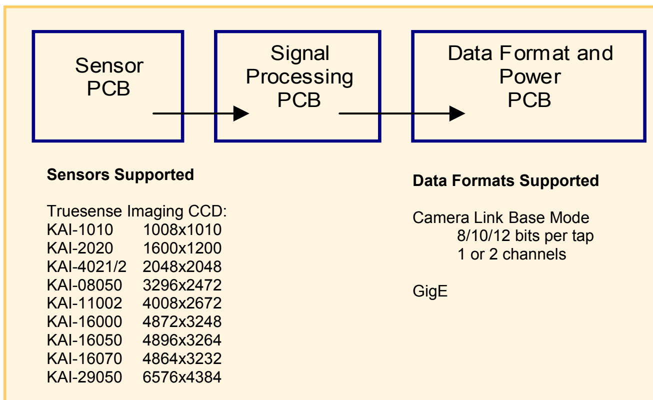
Rugged Machine Vision

Introducing: *Rugged Machine Vision*

The RMV is our newest line of area scan cameras for industrial machine vision and photography. Designed from the ground up with the latest technologies, this line of cameras represents a new standard in digital imaging. The RMV product line builds on the popular XMV products by adding 14 bit analog sampling and 12bit data paths, advanced triggering and CCD readout control, built in detectors that analyze the camera's performance, image processing to remove sensor defects, correct for flat field effects, and on screen tools for analyzing line/columns as well as text overlay. No longer are you required to depend on custom tools to setup and analyze your demanding imaging systems.

RMV Camera Architecture

The RMV camera is based on a modular design which allows for many different image sensors and output formats to be implemented. Through combinations of three different PCB's many different cameras can be created. Each sensor is supported with its own unique circuit board which contains the circuitry needed to drive the sensor and output the digital image data. The Image Processing PCB is common to all cameras and supports the advanced features of the RMV. The data format and power PCB provides the camera link and other signal outputs. From these PCB combinations illunis can manufacture a family of advanced digital cameras.



RMV Camera Modularity Options

1 or 2 tap Sensors: The RMV supports any sensor with one or two video taps. The Truesense Imaging Inc interline transfer CCD's are supported with programmable tap operation so you can select the best output option for your application. The built in image detectors include tap boundary measurement and active tap balancing logic to insure that the two taps gain and offset match as close as possible.

4 tap Sensors: Contact illunis for the manual concerning 4-tap operation.

14 bit ADC's and data path with Tap Reorder: The RMV supports full 14 bit signal sampling and 12bit data paths throughout the signal processing path. This insures that the maximum signal quality is preserved in the processing chain. The tap data is reordered within the RMV to a single raster. Each ADC has programmable gain and programmable active black clamp.

Image Signal Processor (ISP): At the heart of the RMV camera is a very powerful image signal processor that is implemented with a FPGA that contains 1 million gates of logic. The ISP provides all of the sensor control as well as image processing and diagnostics. The ISP is paired with a SDRAM for frame storage and correction table information. The ISP is capable of processing all of its functions in a single pixel clock cycle at up to 80 million pixels per second. Any area sensor to 8Kx8K is supported.

Micro Processor (uP) with FLASH data storage: Supporting the ISP is an advanced microprocessor. The uP is paired with FLASH memory that stores the data for the ISP. The uP also monitors the operation of the RMV and tracks the camera temperature and performance parameters.

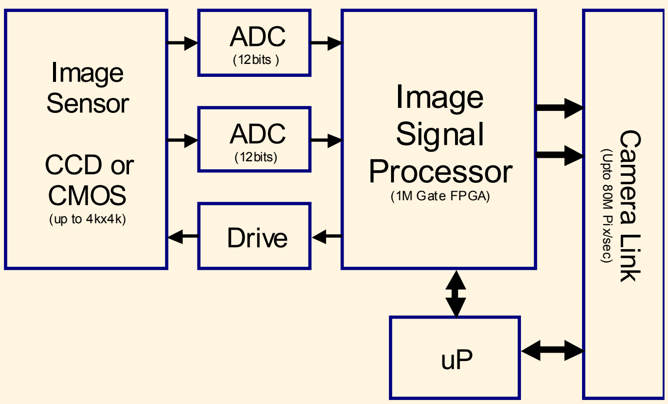
Communication Interface and GUI: Control of the RMV is through a military spec packed based command protocol. The operation of the RMV is represented as modes which can be read as status and written as commands. Packets are error checked and reply with ACK/NACK's A Graphical User Interface (GUI) is included as source code to speed integration. The GUI allows for control of the camera with a standard windows interface.

Built in Test and Industrial Grade Components: Designed for demanding applications, the RMV is built with military derated passive components and industrial grade integrated circuits. Using surface mount technology and very a robust mechanical assembly the RMV can withstand high G and vibration environments. With the design experience of several military level camera projects, we have added extensive built in test features to the RMV. The BIT coverage includes test patterns and CRC measurement for all features of the ISP. The RMV was designed for Rugged environments.

RMV Image Signal Processor Architecture

The RMV ISP is a data driven real time digital signal processor that process a pixel on every clock. The ISP is implemented using a single Xilinx Vertex II FPGA with 1M gates of logic. Here are some of the features:

Custom Timing Generator: All timing signals to the sensor are created by a custom proprietary timing generator. The TG provides complete control of exposure and readout modes of the sensor. Exposure modes include Free run, Free Run Triggered, Free Run Synchronized, Triggered Program Exposure, Triggered Manual/Controlled Exposure, and Triggered Double Exposure. The Trigger and Free run modes can have independent control of Binning, Image correction, LUT activation, Digital gain and offset and Partial Scanning. The RMV can operate in an Asynchronous Reset Mode where the camera free runs, with or without active valids, and upon a trigger signal changes modes and outputs a frame.



RMV Camera Architecture

Tap Reorder (TRO) and Digital Gain/Offset: The RMV camera has an integrated programmable tap reorder circuit. The TRO linearizes the sensor data and allows for horizontal image flipping. This reordered image is used within the RMV for processing. The TRO circuit also includes a digital gain and offset .

Image Detectors: A powerful feature of the RMV is a group of image detectors that measure brightness, sharpness, tap matching, and signal to noise performance. In addition the RMV has a frame counter and cross hair overlay for image center alignment.

Pixel Defect Correction: All sensors have defects and the RMV includes a circuit to correct gross defects through replication or averaging.

Look Up Table (LUT): The hardware LUT built into the ISP can translate any 12 bit pixel to any 12 bit value. The GUI can be used to generate simple LUTs such as gamma curves. LUTs are saved as text files.

On Screen Line/Column/Histogram Plots: Integrated into the ISP are on screen plots of line and column data. These plots extend outside the image area and very useful for evaluating camera performance. The plots run in real time and are overlaid onto the video image. You no longer need to rely on capture cards or custom software to evaluate your image data.

On Screen Text: Another Rugged feature, the On screen text overlay is used to display image detector and or user data in real time.

Raster Measurement: With the multitude of programmable features the RMV can present almost any sized raster to a capture device. To ease integration the RMV includes a built in raster measurement circuit. This circuit provides the total and active lines and pixels within the image output to the camera link device.

Exposure Measurement: The RMV camera incorporates an exposure detector circuit that measures the exact time the camera is exposing the photo diodes. The exposure detector measures the time from the end of the electronic erasure to the end of the photo diode transfer pulse. The exposure is measured in pixel clock periods, 25ns for a 40mhz camera and 33.3ns for a 30mhz camera.

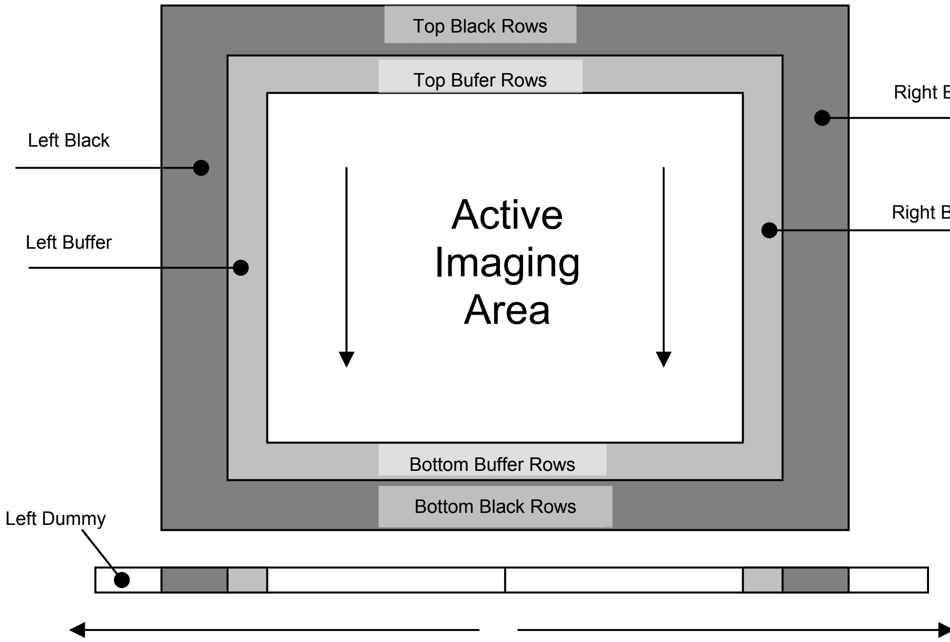
Camera Link Format: The RMV image data is output to a base mode camera link chipset. The image data can be formatted in 8, 10, 12 bit pixels on one or two channels. The maximum data rate is 80 Mpix/sec. This allows the RMV to easily interface with any video capture card or custom circuit.

RMV Sensor information:

The RMV camera's are named by the sensor that is used within them. For example a RMV-2020 uses the Truesense Imaging KAI-2020 sensor. Here is a list of RMV camera and the sensors available.

RMV Camera models			
Mega Pix	**Sensor #**	**Sensor Mfg**	**Camera name**
1.0	KAI-1010	Truesense Imaging	**RMV-1010**
2.0	KAI-2020	Truesense Imaging	**RMV-2M**
4.0	KAI-4021	Truesense Imaging	**RMV-4021**
4.0	KAI-04022	Truesense Imaging	**RMV-4022**
8.0	KAI-08050	Truesense Imaging	**RMV-8M**
11	KAI-11002	Truesense Imaging	**RMV-11002**
16	KAI-16000	Truesense Imaging	**RMV-16000**
16	KAI-16050	Truesense Imaging	**RMV-16050**
16	KAI-16070	Truesense Imaging	**RMV-16070**
29	KAI-29050	Truesense Imaging	**RMV-29M**

The RMV uses Truesense Imaging CCD sensors with a two tap output in a left/ right format. The sensors can be used with either the single left tap or both taps. **The A tap is the right side and the B tap is the left side when viewed on the capture card.**



Consult or website or the Truesense imaging website for sensor specs.

1.1: RMV Overview
Firm ware Updates

Firmware updates are available for all RMV cameras. Our goal is to provide the highest quality product as possible, however over the course of time and with a great deal of testing we do find bugs. As we swat these bugs we release new firmware that incorporate the fixes as well as new features. The FPGA and Microprocessor revision numbers are the key to knowing what version of the firmware you have. Contact our office to find out if you need a firmware update.

Currently RMV cameras must be returned for update.

There is a small handling charge for the updates.

For more information please call at (952) 975-9203 or email: info@illunis.com

1.2: RMV Overview
Warranty

Warranty. illunis warrants that all products will perform in normal use in accordance with specifications for a period of one year from date of shipment. This warranty does not cover failure due to those mechanical and electrical causes defined below as liability of the customer. If the device does not function properly during the warranty period, illunis will at it's option, either repair or replace the unit. In the case of replacement, illunis reserves the right to re-use the original CCD serial number if found to be performing to specification. Illunis does not warranty glassless CCD's. Please refer to the terms and conditions included with your quotation for full warrantee information.

Returns. Products will be considered for replacement for up to one year from the date of shipment. All returns require an RMA number. No returns will be accepted without an RMA number. Contact our office to obtain an RMA number. Returns will be re-tested against the device acceptance criteria and if found to meet those criteria will be shipped back to the customer at the customer's expense.

All returns should be sent to:

Illunis LLC
Attn: RMA coordinator
14700 Excelsior Blvd
Minnetonka, MN 55345
(952) 975-9203

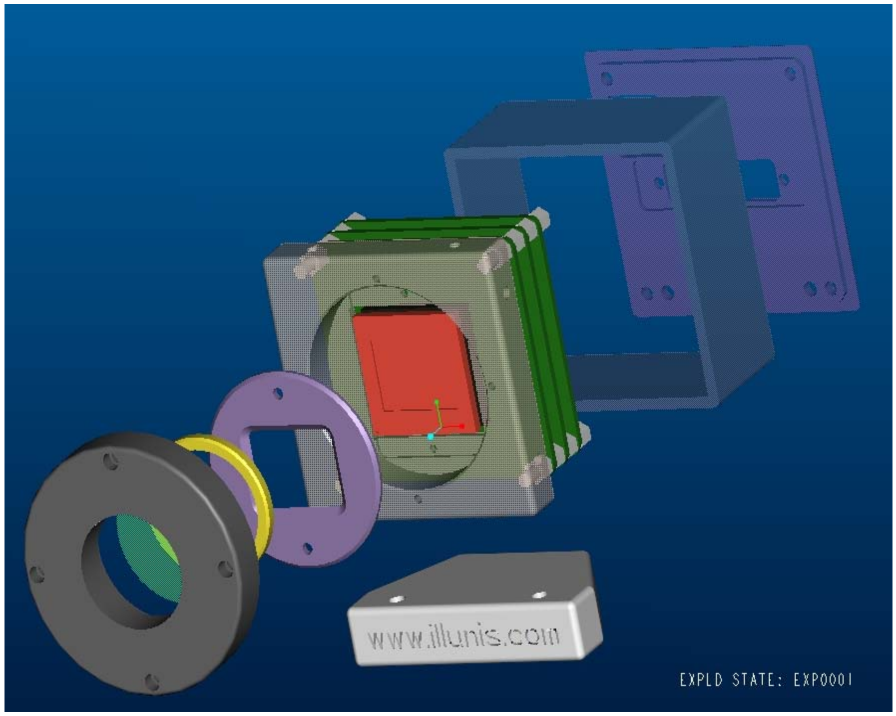
Camera link for Dummies !

A little Humor helps the frustration in setting up a new system, and certainly the basics of how to integrate a camera link camera for the first time. So here are some basic facts about camera link devices:

- **Camera link is controlled by the AIA**: For more information go to http://www.machinevisiononline.org
- **Camera Link is a wiring specification**: The camera link (CL) spec defines wires and signals for transporting video data in various formats over channel link integrated circuits.
- **Camera Link can be used in three modes**: The CL spec defines a base mode that uses a single CL cable, a medium mode and a full mode that use two CL cables.
- **Camera Link uses Channel Link Chips**: Camera Link is based on the National Semiconductor Channel Link chipset. These devices convert the video data from a source (camera), serialize the data, transmit the data using LVDS over twisted wires to a receiver device that converts the data back into the original format. For more information go to: www.national.com/lvds.
- **The Camera Link Cable includes communication:** The CL cable provides a serial communication link to the camera. This link is bidirectional and by default is 9600 baud. The communication rate can be increased but must default to 9600 baud on system startup. The serial communication, from a user application to a CL device, is through a special windows DLL. Some CL capture card manufactures provide
- **The Camera link Cable includes trigger signals**: The CL cable has four camera control signals called CC1, CC2, CC3, and CC4. The RMV camera uses the CC1 signal for the trigger signal. Currently the other control signals are not used in the RMV.
- **The Camera link Cable can transmit one or two pixels per clock**: The base mode camera link used in the RMV can transmit one or two pixels per clock and each pixel can be 8, 10, or 12 bits in size.

Chapter 2: Hardware

Rugged Machine Vision



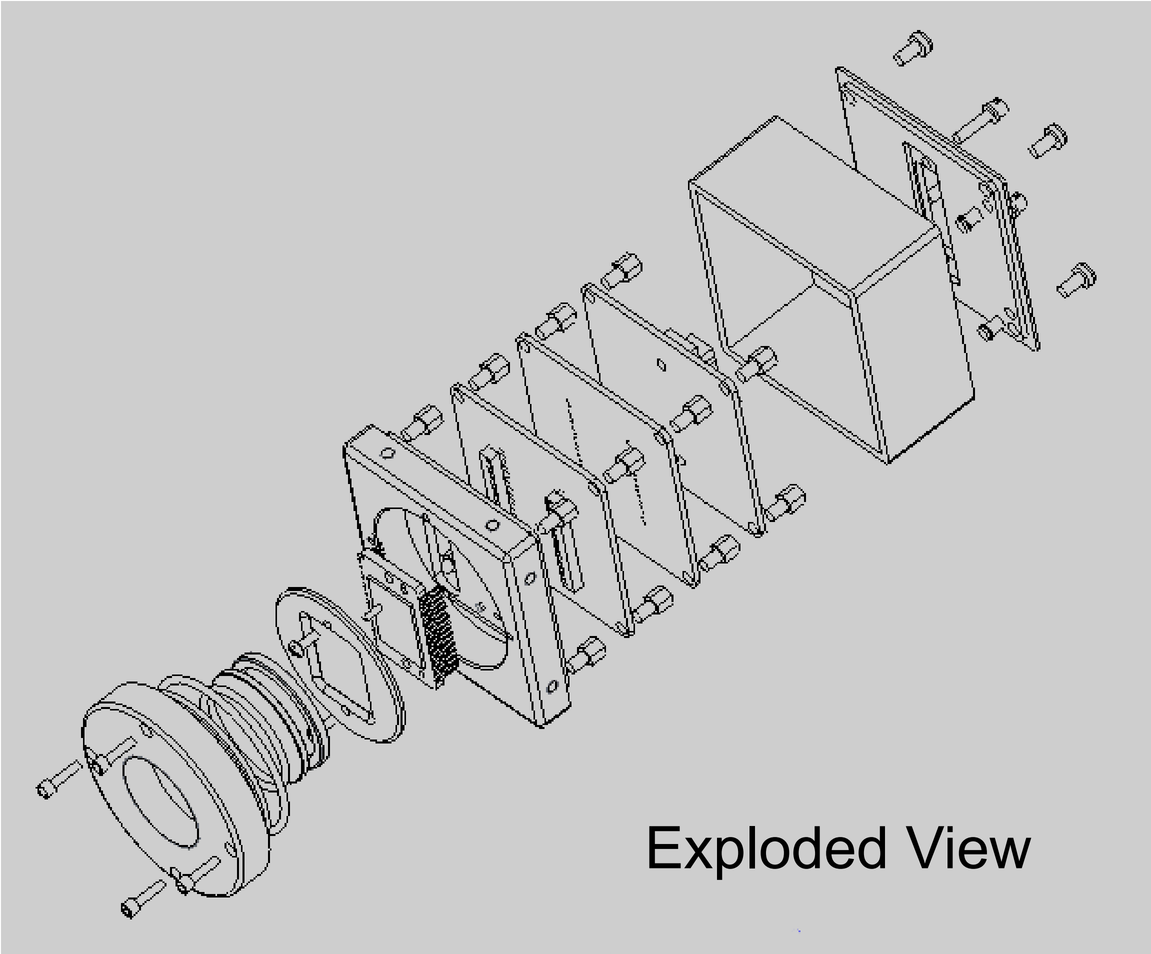
2.0: Hardware Overview

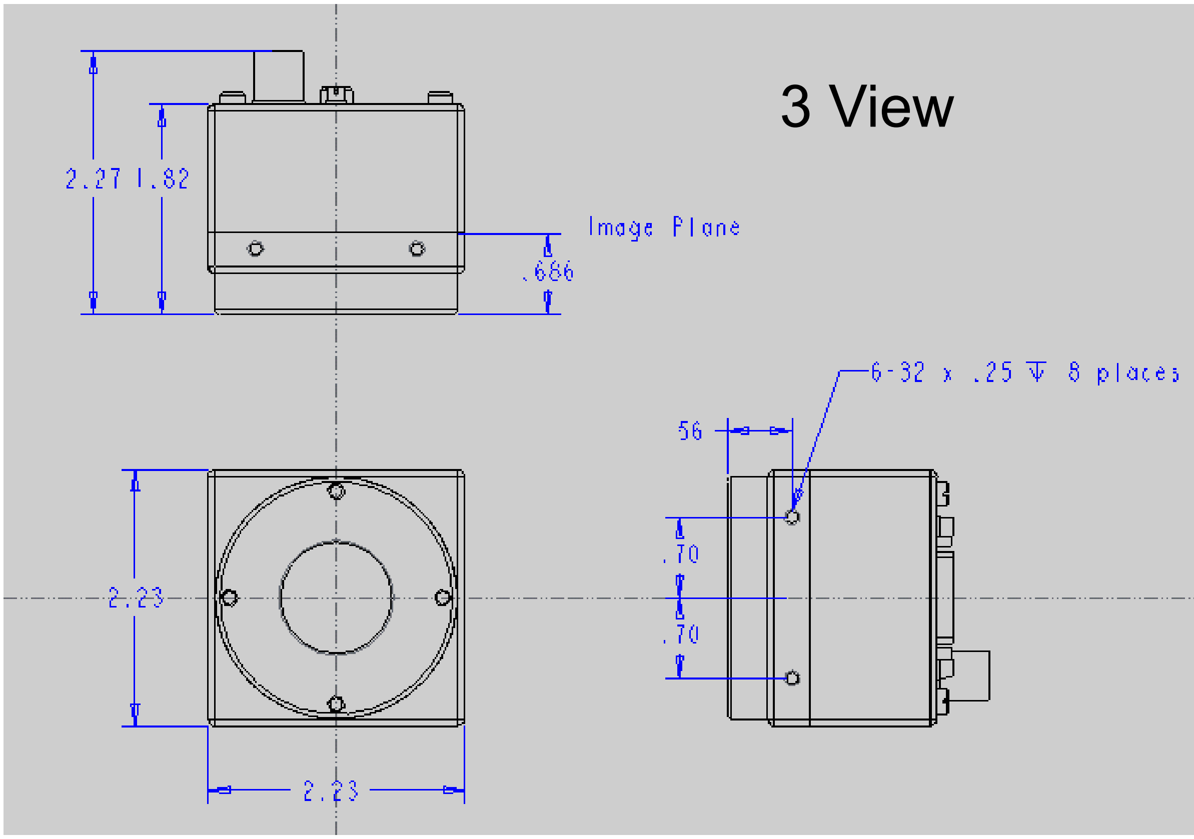
Smaller is better

The RMV hardware design goal was to incorporate advanced features into the smallest size possible. Since the RMV product line incorporates sensors from 640x480 to 10000x7096, the small size of the camera PCB's was dictated by the sensor package size. The RMV circuit design separates the camera into three circuit boards; An imager PCB that contains the electronics need by the specific sensor (this is unique to each sensor), A FPGA/microprocessor PCB that contains the timing generator, control processor, and image processing hardware, and the third PCB is the Power/Communication board which generates the many voltages needed in the CCD image sensor drive circuits and contains the digital image data drive circuits.

The RMV case is machined from 6061 T-6 aluminum on 5-axis CNC machinery. The case was designed using Pro-E CAD software. Solid models of any of the RMV cameras are available for customer use. To obtain a solid model contact our office: Info@ilunis.com

2.1: Hardware Case





2.2: Hardware
CAD Models

CAD Models Detailed Drawings

The RMV case dimensions can be provided as a manufacturing drawings and as a solid model that can be imported into almost any CAD system. For access to these drawings please contact illunis at www.illunis.com , Phone (952) 975-9203, or email: info@illunis.com

CAD Models supported are STEP, IGES, ProE native, and many others

Power Connector and Cable Drawing

RMV Power Cables and connectors

Go to our website where you will find the drawings and pin outpu information for both Camera Link power supplies (Lemo), and Gigabit Ethernet power supplies (Hirose). Custom designed power supplies can be provided as well.

Contact illunis for a pdf copy of this drawing.

2.4: Hardware Considerations

● Do not open or disassemble the camera case or electronics as there are no user adjustments within the camera. This will void your warranty.

● Care must be taken in handling as not to create static discharge that may permanently damage the device.

● Do not apply power with reversed polarity at this will render the camera non functional and void your warranty.

● Camera Link is a DC based interface. The camera and capture device must share the same electrical ground. Failure to do so will destroy the camera link interface chips and/or camera and capture card.

Absolute Maximum Ratings

Input Voltage: 10 to 16V DC
Storage Temperature: -40C to +70C

Recommended Maximum Ratings

Input Voltage: 11 to 14V DC
Operating Temperature: -20C to +60C
Most cameras operate beyond these temperature limits, please call illunis for details.

Recommended Operating Conditions

Input Voltage: 12V DC
Operating Temperature -5C to 540C
Relative humidity should not exceed 80% non-condensing

Thermal interface

The RMV camera contains many advanced circuits and performs at very high clock speeds and thus requires careful consideration for thermal cooling. The camera should be used either with a lens and/or a solid mechanical mount that acts as a heat sink.

Power Consumption

The RMV camera was designed to be as small as possible and as such has a high energy density. The various operating modes of the RMV will change the power consumption from the base line. In particular the binning and partial scan modes require more power. The triggered modes are lowest in power when the camera is waiting for a trigger. Special versions of the RMV with lower clock speeds are available with lower power consumption.

Special notes for Rugged environmental use

The RMV cameras are designed using military 0.6 stress ratings on all passive components and uses industrial temperature range active components when ever possible. The RMV is assembled using standard commercial techniques that DOES NOT HARDEN the mechanical components against vibration. It is highly recommended that any use of the RMV in any application that requires high vibration and temperature ranges that the hardware be inspected and modified using adhesives to retain the mechanical components.

Interline Sensor Options

(All sensors are available in color and mono except where noted)

KAI-1010	1008 x 1010
KAI-2020	1600 x 1200
KAI-2170	1920 x 1080 (HDTV, coming Q3 2013)
KAI-4021	2048 x 2048
KAI-4022	2048 x 2048
KAI-08050	3296 x 2472
KAI-11002	4004 x 2672
KAI-16000	4872 x 3248
KAI-16050	4896 x 3264
KAI-16070	4864 x 3232
KAI-29050	6576 x 4384

Cable Options

Cable with strobe output
Basic Power Only Cable

Lens Mounting Options* (Call for current solid models and drawings)

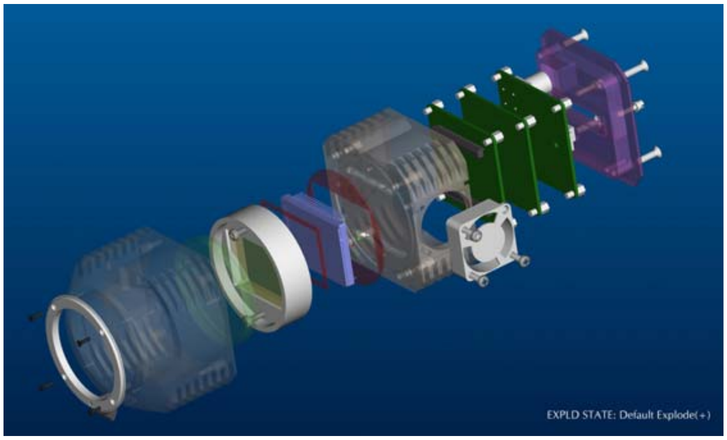
C-Mount
C-Mount with 25mm filter mount

F-Mount (desktop) with 1/4-20 mount
F-Mount with flange for RMV-8M, RMV-11002, RMV-16000, RMV-16050, RMV-16070, RMV-29050
F-Mount with flange for RMV 2M, 4021, 4022

Birger Mount, Hasselblad mount, Rollei mount, custom mount
No lens mount

Case Options (Call for solid models and drawings)

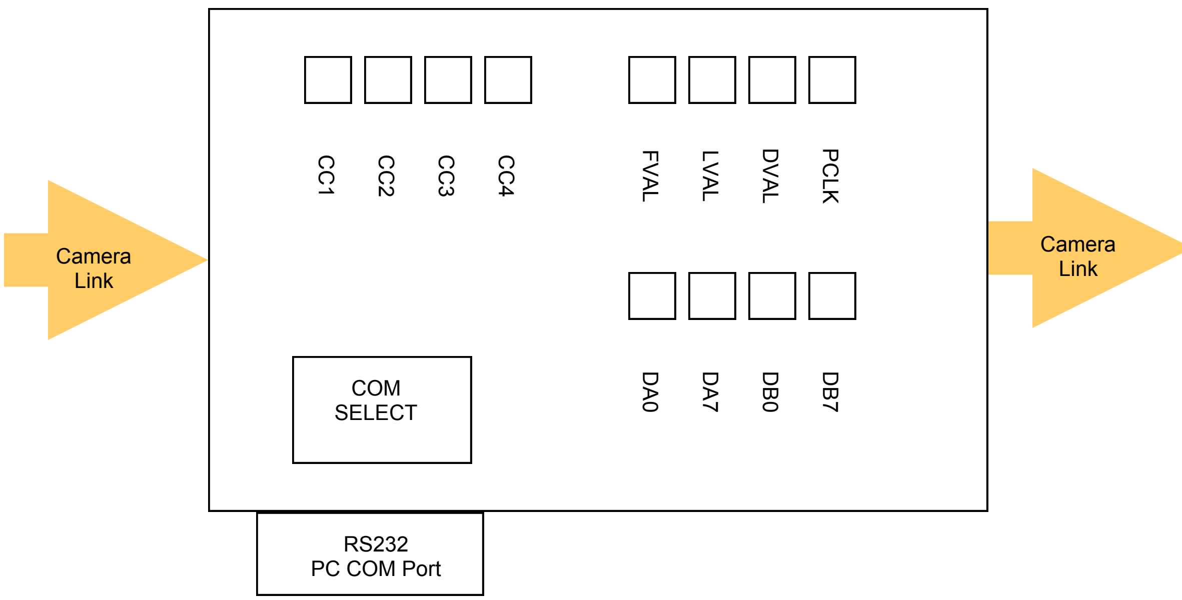
Standard case
OEM Case

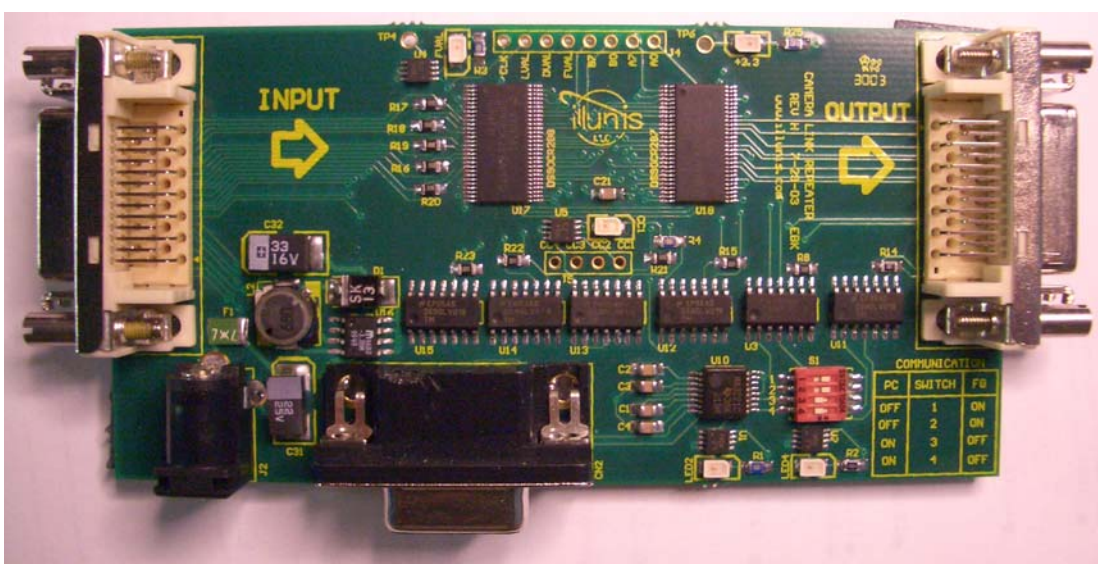


Camera Link Repeater

A special test board is available for use as a camera link repeater (CLR) and for setup of camera link systems. The CLR is a circuit that de-serializes the camera link data, provides this data as LVTTL and then re-serializes the CL data for transmission to a capture card. The CLR also provides an option to redirect the communications data from the capture card to a standard windows serial port.

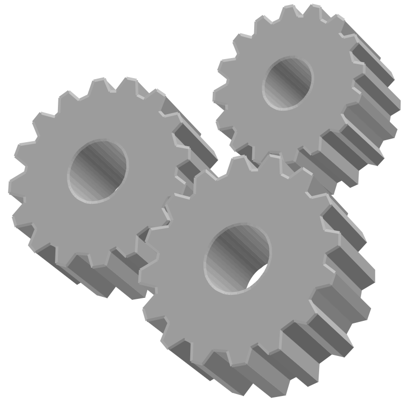
The CLR is powered with 12VDC.





Chapter 3: Software ICD

Rugged Machine Vision

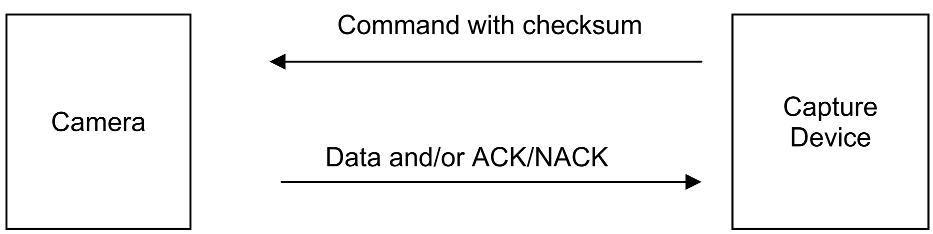


3.0: Software ICD
Overview

The RMV software interface (commonly called a Inter-Connect-Description or ICD) was developed for high reliability applications. The ICD incorporates error checking and a handshake protocol which responds with either a positive or negative acknowledge signal. The communication path from frame grabber to the RMV is through the Camera Link cable. The Camera Link committee has specified that devices connected must first communicate at 9600 baud. This default baud rate is certainly very slow for devices such as the RMV camera. The RMV has a selectable baud rate for faster communication speeds.

The RMV microprocessor is a flash programmable device with many features vital to the operation of the RMV camera. Some of these include:

A hardware UART used for serial communications.
A watchdog timer used to monitor communication errors and system faults.
Onboard RAM and EEPROM for saving camera settings
Parallel data bus for high speed interfaces to the FPGA and NAND FLASH memories
Brown out detection and reset



3.1: Software ICD
Serial Interface

SERIAL INTERFACE PROTOCOL

Implementation

Camera communication is accomplished via asynchronous serial communication according to EIA Standard RS 232 C through the Camera Link cable.

Data rate: Full Duplex, 9600 baud.
1 START bit.
8 DATA bits – The LSB (D0) is transfered first.
1 STOP bit.
No parity.

Command Packets

Protocol

The camera is controlled through command packets. The camera is considered a slave device and never generates data without a read request. The data packet formatting is described in detail below – **note** That the checksum is calculated only on the 4 ascii characters comprising the Data.

Data Packets

Data packets are of either 'read' or 'write' types. For example to read the camera serial number, the packet sent to the camera would be {r07000002fe} to which the camera would respond by issuing an acknowledge character ! followed by the response {r0700sssscc}, where ssss is the camera serial number and cc is the checksum calculated in hex as 0x0100 – (ss (high byte hex) + ss (low byte).

Packet Format

1 Char	2 Char	2 Char	2 Char	4 Char	2 Char	1 Char	1 Char
Start	**Command**	**Target**	**Index**	**Data**	**Checksum**	**End**	**Ack/Nack**

Start:
Indicates the Start of the frame
Size = 1 ascii character
Value = 123 Decimal (ascii {)

Command:
Command descriptor
Size = 1 ascii character
Value = 114 Decimal (ascii r) for Read
Value = 119 Decimal (ascii w) for Write

Target:
Command descriptor
Size = 2 ascii characters

Index:
Command descriptor
Size = 2 ascii characters

Data:
The data transferred
Size = 4 ascii characters

Checksum of Data only (default)
Size = 2 ascii characters - Intel-Standard - two's compliment of sum of data.

Example1: Data = 2002, checksum = lower byte of (0x100 – (0x20 + 0x02)) = 0xde

Example2: Data = 0000, checksum = lower byte of (0x100 – (0x00 + 0x00)) = 0x00
Example3: Data = fef0, checksum = lower byte of (0x100 – (0xfe + 0xf0)) = 0x12

Checksum of Command and Data:
checksum(comandindex) + checksum(data)

Example4: Command = 0400, data = 0x0001
(0x100 – (0x04 + 0x00)) = 0xFC
(0x100—(0x00 + 0x01)) = 0xFF

Checksum = lower byte of 0xFC + 0xFF => 0xFB

End
Indicates the End of the frame
Size = 1 ascii character
Value = 125 Decimal (ascii })

Ack/Nack
Positive acknowledge - Negative acknowledge
Size = 1 ascii character
Ack Value = 33 Decimal (ascii !)
Nack Value = 63 Decimal (ascii ?)

COMMAND DESCRIPTIONS

Read Command Structure

The camera parses the sequence byte by byte. An invalid read command, target or index will cause the camera to issue an NACK. The Host (You) will generate dummy data with a valid checksum then an end. The camera will respond with an ACK and re send the command with valid data and checksum. If the Host detects an error, it will re issue the command.

Host {r tt ii 0 0 0 0 cc}, camera issues !
Camera issues {r tt ii data data data data cc} (NOTE no ACK)

Write Command Structure

The camera parses the sequence byte by byte. An invalid write command, target, index or checksum will cause the camera to issue a NACK, otherwise the write sequence will complete and the camera will issue an ACK after the command has been executed. The camera receives the checksum from the Host.

Host {w tt ii data data data data cc} camera issues !

Error Checking

The camera parser is character by character and will respond with an immediate NACK if any unrecognised command, target, index or checksum occurs.

Communication Timeouts

The camera micro controller uses a hardware watchdog timer that will time out if the time between bytes are longer than ??? ms. When sending command frames to the camera the host must not have significant delays between bytes sent.

Command Table

Target	Index	**Description**	Read Write	Modes
Camera Control				
04	00	Sensor Taps	Write	0x0000 = Single Tap 0x0001 = Dual Tap
04	01	Camera link Data Channels	Write	0x0000 = Single channel output 0x0001 = Dual channel output 0x0002 = Normal dual channel 0x0003 = Swap dual channel
04	02	Clamp Mode	Write	0x0000 = Frame Clamp 0x0001 = Line Clamp
04	03	Readout Mode Select	Write	0x0000 = Free Run 0x0001 = Trigger Program Exposure 0x0002 = Trigger Manual Exposure 0x0003 = Trigger Double Exposure 0x0004 = Not Used 0x0005 = Async Reset Enabled 0x0006 = Async Reset Disabled 0x0007 = Enable Runs Valids 0x0008 = Disable Runs Valids 0x0009 = Trigger Source CL 0x000a = Trigger source External (OEM 0x000b = Trigger Overlap Exposure Enable 0x000c = Trigger Overlap Exposure Disable
04	04	Mode Register write lines to 0428 and 0429 prior to binning M = 0 Common – both trigger and free run M = 8 Free Run Only M = 4 Trigger Only	Write	0xM000 = Bin enable 0xM001 = TBD 0xM002 = Disable bin 0xM003 = Enable partial Scan 0xM004 = Disable Partial Scan 0xM005 = Enable Digital Gain and offset 0xM006 = Disable Digital Gain and offset 0xM007 = Enable LUT 0xM008 = Disable LUT 0xM009 = Enable PDC enables once loaded (call 041c000b first which leaves PDC on in common mode) 0xM00a = Disable PDC 0xM00b = Enable Single Tap CCD 0xM00c = Enable Dual Tap CCD 0xM00d = Enable Single Channel CL 0xM00e = Enable Dual Channel CL 0x000F = Enable Bayer Bin 0x0010 = Disable Bayer Bin 0x0011 = Enable FFC 0x0012 = Disable FFC 0x0013 = Long Vcount enable 0x0014 = Long Vcount disable

04	06	Test Pattern	Write	0x0000 = Normal Video 0x0001 = Input (CCD)Test Pattern 0x0002 = Output Test Pattern
04	07	Camera Temperature	Read	
04	08	Over scan mode	Write	0x0000 = Disable overscan Mode 0x0001 = Enable overscan Mode
04	09	Baud Rate	Write	0x0000 = 9600 0x0001 = 19200 0x0002 = 38400 0x0003 = 57600 0x0004 = 115200
04	D2	Set Camera Link Boot Baud Rate (Requires re-boot)	R/W	0x0000 = 9600 0x0001 = 19200 0x0002 = 38400 0x0003 = 57600 0x0004 = 115200
04	D3	External Serial Boot Baud Rate (Requires reboot)	R/W	0x0000 = 9600 0x0001 = 19200 0x0002 = 38400 0x0003 = 57600 0x0004 = 115200
04	0a	Partial Scan Start Line	R/W	
04	0b	Partial Scan Stop Line	R/W	
04	0c	Micro BIT initiate	Write	0x0000 = Clear Bit Status Register 0x0001 = PBIT 0x0002 = IBIT
04	0d	Bit Depth	Write	0x0000 = 12 bit mode 0x0001 = 10 bit mode 0x0002 = 8 bit mode 0x0003 = Enable bottom 8 bits 0x0004 = Disable bottom 8 bits
04	0e	Strobe Control	Write	0x0000 = negative strobe polarity 0x0001 = positive strobe polarity 0x0002 = Active during free run 0x0003 = Disable during free run
04	11	OSD lines	Write	0x0000 disable 0x0001 line plot 0x0002 column 0x0008 line display 0x0009 filled display 0x000a enable color mode 0x000b disable color mode
04	12	Line Plot Offset	R/W	
04	13	Line Plot Scale	R/W	
04	14	Line Plot Line of Interest	R/W	

04	15	OSD Text	Write	0x0000 disable text overlay (All) 0x0001 enable OSD (Detectors) 0x0002 update display window 0x0003 enable 2X text size 0x0004 enable 1X text size 0x0005 enable OSD (Raster) 0x0006 enable OSD (Revision) 0x0007 enable OSD (Frame) 0x0008 enable OSD (GNU detector) 0x0009 enable OSD (AE)
04	16	OSD Text Window X location	Read/Write	
04	17	OSD Text Window Y location	Read/Write	
04	18	LUT load	W	Loads LUT based on mode
04	45	LUT load mode	R/W	0x0000 = load from com port 0x0001 = load from com port and save to EEPROM 0x0002 = load from EEPROM
04	46	Load Gamma LUT	Write	Data is a 0-100 = gamma * 100
04	19	Show Detectors	Write	0x0000 = Tap A Crack 0x0001 = Tap B 0x0002 = AE Window 0x0003 = AF Win 0x0004 = SNR Left 0x0005 = Right 0x0006 = Cross hair 0x0007 = AF Data 0x0008 = AF Data Full Screen 0x0009 = disable
04	1a	Read Detectors	Read	0x0000 = Tap A Crack 0x0001 = Tap B 0x0002 = AE Window 0x0003 = AF Win 0x0004 = Left SNR Sum 0x0005 = Left SNR Sum of Squares 0x0006 = Left SNR # of Samples 0x0007 = Right SNR Sum 0x0008 = Right SNR Sum of Squares 0x0009 = Right SNR # of Samples 0x000a = Frame Counter 0x000b = Left SNR Max Value 0x000c = Right SNR Max Value 0x000d = Number of saturated pixels
04	1b	System Registers	Read	0x0000 = Read Pixels/line 0x0001 = Read Active pixels/line 0x0002 = Read Lines per frame 0x0003 = Read Active lines per frame 0x0004 = Read TPW 0x0005 = TRO Left Start 0x0006 = TRO Right Start 0x0007 = TRO Size 0x0008 = LVAL Start 0x0009 = Stop 0x000a = FVAL Start 0x000b = Stop 0x000c = CCD Type 0x000d = FPGA Revision 0x000e = Read TPD 0x000f = SNR Left 0x0010 = SNR Right 0x0011 = Crack detector position 0x0012 = Read Exposure value low 0x0013 = Read Exposure value hi 0x0014 = Read CRC

04	1b	System Registers (continued)	Read	0x0019 = WB/GNU CLR0 0x001a = WB/GNU CLR1 0x001b = WB/GNU CLR2 0x001c = WB/GNU CLR3
04	1c	Pixel Defect	Write	0x0000 = Disable Column Mode 0x0001 = Enable Column Mode 0x0002 = Load PDM From EEPROM leaves PDC on in common mode 0x0003 = Disable PDC2 Column Mode 0x0004 = Enable PDC2 Column Mode 0x0005 = Disable all PDC
04	1d	Auto Exposure	Write	0x0000 = Disable AE 0x0001 = Enable Fast AE 0x0002 = Enable Slow AE 0x0003 = Enable small AED counter (1mpix) 0x0004 = Enable large AED counter(16mpix) 0x0005 = Enable AED averaging 0x0006 = Disable AED averaging
04	1e	AE Set point	R/W	
04	1f	AE Hysteresis	R/W	
04	20	AE max gain	R/W	In Digital Gain untis
04	21	AE min gain	R/W	
04	22	AE max exposure	R/W	(min erasure)
04	23	AE min exposure	R/W	(max erasure)
04	24	Common gain - Digital	R/W	
04	25	Free Run erasure	R/W	
04	26	AE detector	Read	
04	27	System Registers write data to EEDATA 030c prior to calling	Write	0x0004 = Write TPW 0x0005 = Write TRO Left Start 0x0006 = Write TRO Right Start 0x0007 = Write TRO Size 0x0008 = Write LVAL Start 0x0009 = Write LVAL Stop 0x000a = Write FVAL Start 0x000b = Write FVAL Stop 0x000e = Write TPD 0x000f = SNR Left 0x0010 = SNR Right 0x0011 = Crack Location
04	28	Trigger V Bin / Dec	R/W	Read/Write values 1 - 13
04	29	Trigger H Bin / Dec	R/W	Read/Write values 1 - 16
04	2a	Write Free Run V Bin	R/W	Read/Write values 1 - 13
04	2b	Write Free Run H Bin	R/W	Read/Write values 1 - 16
04	2c	Left Tap Digital gain	R/W	
04	2d	Left Tap Digital offset	R/W	
04	2e	Right Tap Digital gain	R/W	
04	2f	Right Tap Digital offset	R/W	
04	36	Master Gain	R/W	
04	37	Master Offset	R/W	
04	38	Master DGO Enable	R/W	1 = enable, 0 = disable

04	31	Mode presets – OEM	Write	0x0000 = N/A 0x0001 = Linear LUT 0x0002 = Inverted LUT 0x0003 = Preview LUT 0x0004 = Gamma LUT 0.45 0x0005 = Gamma LUT 0.60 0x0006 = Gamma LUT 0.70 0x0007 = Gamma LUT 0.80
04	32	AE VSYNC Count	R/W	# of frames between AE changes Set to 3 for free run mode Set to 1 for triggered modes
04	33	AE Exposure Denominator	R/W	
04	34	AE Gain Denominator	R/W	
04	35	WB/GNU Tap Select	R/W	0x0000 = left tap (default on power up) 0x0001 = right tap
04	40	FFC table load	W	Activates FFC
04	41	FFC test	W	Loads entire FFC table with data. Where 0x1000 = 1x, 0x1800 = 1.5x
04	42	FFC Master gain	R/W	Sets FFC master gain
04	43	FFC load mode	R/W	0x0000 = load from com port 0x0001 = load from com port and save to EEPROM 0x0002 = load from EEPROM
04	04	Mode Register	W	0x0011 = Enable FFC 0x0012 = Disable FFC
Camera Mode and Status				
05	00	Camera mode/status	Read	0x0000 = read mode register 1 0x0001 = read mode register 2 0x0002 = read mode register 3 0x0003 = read mode register 4 0x0004 = read mode register 5 0x000B = read mode register 6 0x000C = read mode register 7 0x000D = read mode register 8 0x0005 = read status register 1 0x0006 = read status register 2 0x0007 = read status register 3 (IBIT) 0x0008 = read status register 4 (IBIT)
Camera Configuration				
07	00		Read	0x0000 = Camera Model 0x0001 = Camera Hardware rev 0x0002 = Camera Serial Number 0x0003 = Micro firmware rev 0x0004 = FPGA major revision 0x0005 = Sensor Serial Number 0x0006 = Clock Rate 0x0007 = FPGA Sub/minor revision 0x0008 = Micro Sub/minor revision (rev >E7) 0x0009 = Camera type (rev >E7) 0x000A = FPGA Clk Speed (rev >E7)

Timing Generator				
02	00	Set Trigger Time MS	Read/Write	ms * 100 (0x0064 = 1.0ms)
02	01	Set Trigger Time US	Read/Write	us
02	02	Set Free Run Time MS	Read/Write	ms * 100
02	03	Set Free Run Time US	Read/Write	us
02	04	Transfer Pulse Delay	Read/Write	
02	05	Soft Trigger Time	Write	Software trigger in ms
02	06	Set trigger high	Write	Sets internal trigger high (active)
02	07	Set trigger low	Write	Sets internal trigger low
02	0A	TG Erasure	Read/Write	
02	0B	Trigger Sub Pulse Delay	Read/Write	Default = 0x0001
Memory Management				
03	00	Save Camera State	Write	Wait for acknowledge before re-moving power
03	02	Restore Factory State	Write	Wait for acknowledge before re-moving power
03	03	Copy User to Factory	Write	Wait for acknowledge before re-moving power
03	04	Save substrate DAC value	Write	Dummy data
03	05	Copy factory to all USER	Write	Warning: This can take time !
03	06	Copy USER# to USER#	Write	Top byte is SRC USER Bottom byte is DST USER
03	07	Set USER #	Write	Copies USER to ACTIVE, loads it, and performs soft reset Bottom byte is USER#
03	08	Number of USER configs	Read	4 is the current limit
03	09	Reset EEPROM CRC	Write	
03	20	Read 64 bytes from EEPROM		Checksum = 0x00
03	0c	EEPROM data and tempo-rary location for operations requiring data and address	Write	
03	0d	EEPROM Word	Read/Write	0xaaaa = address Read address directly Write data word to 030c then write 030d with address
03	0e	EEPROM Byte	Read/Write	0xaaaa - address Read address directly Write data byte to 030c then write 030e with address
03	FF	EEPROM erase	W	Erases EEPROM with FF Very dangerous !

Special Commands				
04	E0	Smear Reduction	Write	0x0000 = Disable SRC 0x0001 = Enable SRC subtraction 0x0002 = Enable SRC average 0x0004 = Enable 16 line over-scan 0x0005 = Enable fast ASYNC reset flush 0x0006 = Disable fast ASYNC reset flush
04	FF	Base Reset	Write	Resets camera mode to: free run, runs valid enabled, no binning, no partial scan, no line or text displays, no LUT, no PDC, no digital gain or offset, no test pattern, reset the LVAL and FVAL defaults. AE detector counter set to small size. enable strobe in free run mode Auto Tap Matcher off
04	F0	Recce Free Run		Removed
04	F1	Recce Triggered		Removed
04	F2	Recce Window		Removed
04	F3	Recce Binning		Removed
04	D8	Checksum Mode (Cleared on restart)	Write	0x0000 = Checksum of data 0x0001 = Checksum of command and data
04	D0	Power Up	Write	Resets camera and powers up circuits
04	D1	Power Down	Write	Puts the camera into low power mode
09	00	Auto Tap Matcher	R/W	0 = off, 1 = on

There are additional ICD commands for specialized control of the RMV camera. Information on these commands require a nondisclosure agreement. Please contact illunis at email: info@illunis.com

External UART Commands (Rev >=E7 hardware only)

0x11	00	Init Baud Rate	Write	0x0000 = 9600 (Default) 0x0001 = 19200 0x0002 = 38400 0x0003 = 57600 0x0004 = 115200
0x11	01	Put character	Write	Puts character to external UART
0x11	02	Clear buffer	Write	Clear receive buffer
0x11	03	Get character	Read	Returns character if buffered or 0 if buffer is empty
0x11	04	Get buffer count	Read	Returns number of characters in receive buffer
0x11	05	Get buffer size	Read	Returns total size of receive buffer

Canon Lens Control Commands (Rev >=E7 hardware only)

0x12	0x00	Canon Lens Init.	Write	Canon Lens Controller Initialization (required)
0x12	0x00	Read Lens error	Read	0 = no error 5 = lens not initialized 1 = bad command 7 = no shutter in lens 2 = lens set to manual focus 8 = bad power 3 = no lens 9 = bad lens library 10 = lens communication error
0x12	0x01	Canon command	Write	Two character command. Top byte = first char. Bottom byte = second char. Sent to controller as Ch1 Ch2 <cr>.
0x12	0x02	Lens ID	Write	Information is in the serial read buffer
0x12	0x03	Lens Hdw Vers.	Write	Information is in the serial read buffer
0x12	0x04	Focus to Infinity	Write	
0x12	0x05	Focus to Zero	Write	
0x12	0x06	Focus Absolute	Write	Data = Focus position
0x12	0x07	Position of Focus	Write	Information is in the serial read buffer
0x12	0x18	Focus Incremental	Write	Data = signed incremental position change Positive number move focus to infinity. Negative numbers move focus to zero.
0x12	0x08	Focus Distance	Write	Information is in the serial read buffer
0x12	0x0A	Response Mode	Write	0 = non-verbose, 1 = verbose
0x12	0x0B	Aperture Open	Write	
0x12	0x0C	Aperture Close	Write	
0x12	0x0D	Aperture Absolute	Write	Data = Aperture position
0x12	0x18	Aperture Incremental	Write	Data = signed incremental position change (negative numbers open IRIS, positive numbers close IRIS)
0x12	0x0E	Position of Aperture	Write	Information is in the serial read buffer
0x12	0x10	Image Stab.	Write	Image Stabilization
0x12	0x40	Auto Focus	Write	Requires free run mode and correct exposure Works only on static images. The AF algorithm will scan the image in three passes to determine the best focus. The AF may take up to 10 seconds to complete.
0x12	0x50	Auto IRIS	Write	Data = AE detector set-point. The IRIS will be driven so that the AE detector will match the set-point. The desired brightness may not be possible as a change in exposure may be needed.

System & Status

System status can be read from mode registers and from the system built in test status register.

Quick FAQ's:
- ►These commands are very useful for determining the state of the camera.
- ►The FPGA major and minor revision should be checked by application software to match with expected levels.
- ►The clock rate must be divided by 100

Serial Commands

Target	Index	Command	R/W	Description
04	1b	System Registers	R	0x0000 = Read Pixels/line 0x0001 = Read Active pixels/line (in LVAL) 0x0002 = Read Lines per frame 0x0003 = Read Active lines per frame (in FVAL) 0x0004 = Read TPW 0x0005 = TRO Left Start 0x0006 = TRO Right Start 0x0007 = TRO Size 0x0008 = LVAL Start 0x0009 = LVAL Stop 0x000a = FVAL Start 0x000b = FVAL Stop 0x000c = CCD Type 0x000d = FPGA Revision 0x000e = Read TPD 0x000f = SNR Left 0x0010 = SNR Right 0x0011 = Crack detector position 0x0012 = Read Exposure value low 0x0013 = Read Exposure value hi 0x0014 = Read CRC
07	00	Camera Parameters	R	0x0000 = Camera Model 0x0001 = Camera Hardware rev 0x0002 = Camera Serial Number 0x0003 = Micro firmware rev 0x0004 = FPGA major revision 0x0005 = Sensor Serial Number 0x0006 = Clock Rate 0x0007 = FPGA Sub/minor revision 0x0008 = Micro Sub/minor revision (rev >E7) 0x0009 = Camera type (rev >E7) 0x000A = FPGA Clk Speed (rev >E7)

System & Status Continued

Serial Commands

Target	Index	Command	R/W	Description
07	00	Camera Parameters	R	0x0000 = Camera Model 0x0001 = Camera Hardware rev 0x0002 = Camera Serial Number 0x0003 = Micro firmware rev 0x0004 = FPGA/Timing Generator rev 0x0005 = Sensor Serial Number 0x0006 = Clock Rate 0x0007 = FPGA sub revision
05	00	Camera mode and status registers	R	0x0000 = read mode register 1 0x0001 = read mode register 2 0x0002 = read mode register 3 0x0003 = read mode register 4 0x0004 = read mode register 5 0x0005 = read status register 1 0x0006 = read status register 2 0x0007 = read status register 3 0x0008 = read status register 4 0x0009 = read status register 5 0x000A = read status register 6 0x000B = read mode register 6 0x000C = read mode register 7 0x000D = read mode register 8 0x000E = read hardware stataus register 2

Mode Register #1

Bit	Name	Description
15	Strobe Polarity	1 = Positive Strobe
14	On Screen Text Enabled	
13	Output Test Pattern Enabled	
12	Input Test Pattern Enabled	
11	Large AED Detector	0 = small detector (1MP), 1 = large detector (16MP)
10	Dual Tap Enabled	
9	TOE:	Triggered Overlap Exposure
8	Fast AE algorithm	1 = fast, 0 = iterative
7	TDE:	Trigger Double Exposure
6	TME:	Trigger Manual Exposure
5	TPE:	Trigger Program Exposure
4	Free Run Enabled	Free Run Mode
3	Runs Valid Enabled	Valids (FVAL/LVAL/DVAL) are enabled in Free Run Mode
2	AE Inside Hysteresis	
1	AE Exposure Mode	1 = exposure mode, 0 = gain mode
0	AE Mode Enabled	

Mode Register #2		
Bit	**Name**	**Description**
15	FWM in preview	0 = Triggered, 1 = Preview fast watch mode
14	Fast Watch Mode Enabled	
13	Over Scan Enabled	Sensor Over Scan
12	PDC Column Mode	PDC: 0 = Pixel correction, 1 = column correction mode
11	D5_Mode	Backwards compatibility mode with the D5 firmware (OEM customers)
10	Channel Swap Enabled	Swaps camera link channels in dual channel mode
9	Single Channel Readout	Single channel camera link output
8	Bottom 8 Readout	Outputs the bottom 8 bits of the 12 bit ADC data as the 8 msb's
7	8 Bit Readout	Camera link readout mode
6	10 Bit Readout	Camera link readout mode
5	12 Bit Readout	Camera link readout mode
4	Tap Matcher Status	1 = on, 0 = off
3	Frame/Line Clamp Mode	0 = Line Clamp, 1 = Frame Clamp (Not recommended)
2	ASYNC RESET Enabled	Allows triggered frames in Free Run Mode
1	LUT loaded	
0	OSD 2X Enabled	

Mode Register #3		
Bit	**Name**	**Description**
15	SRC Over scan	Adds 16 lines of over scan to the sensor readout
14	TBD	
13	SRC Average	Averages data in smear reduction circuit
12	OSD Filled Plot	
11	SRC Enable	Smear Reduction Correction
10	OSD Column Enabled	
9	OSD Line Enabled	
8	Free Run Partial Scan Enabled	
7	Trigger Source External	Rev E hardware and OEM cameras only
6	Flush Gate	
5	OSD Color Mode	Enlarges the tap match window to two pixels wide to handle Bayer patterns
4	Free Run PDC Enabled	
3	Free Run LUT Enabled	
2	Free Run DGO Enabled	DGO = Digital Gain & Offset
1	Free Run Decimation Mode	
0	Free Run Bin Mode	

Mode Register #4		
Bit	**Name**	**Description**
15	Command + Data Checksum	
14	115200 Baud Enabled	
13	57600 Baud Enabled	
12	38400 Baud Enabled	
11	19200 Baud Enabled	
10	9600 Baud Enabled	
9	Trigger Overlap Exposure	
8	Trigger Partial Scan Enabled	
7	Not Used	OSD screen type bit 2
6	Not Used	OSD screen type bit 1
5	Not Used	OSD screen type bit 0
4	Trigger PDC Enabled	
3	Trigger LUT Enabled	
2	Trigger DGO Enabled	
1	Trigger Decimate	
0	Trigger Bin	

Mode Register #5		
Bit	**Name**	**Description**
15	AE Time base algoritm	Always 1 for Rev E
14	Trigger Bayer Bin	
13	FFC Table loaded	
12		
11	Show AF data full screen	
10	Show AF Data	
9	Show SNR Right Detector Window	
8	Show SNR Left Detector Window	
7	Show AF Detector Window	Auto Focus detector window
6	Show AE Detector Window	Auto Exposure detector window
5	Show Tap B Crack Detector Window	Tap B is the Left Tap of the CCD
4	Show Tap A Crack Detector Window	Tap A is the Right Tap of the CCD
3	TBD	
2	Power Down	
1	AE Close IRIS Request	Indicates to the user control software that the image is to bright
0	AE Open IRIS Request	Indicates to the user control software that the image is to dim

Mode Register #6

Bit	Name	Description
15	TPD SEL1	
14	TPDSEL 0	
13	BIN AVE 1	BIN1/0 average functions (00 = none, 01=DIV2, 10=DIV4, 11=DIV8).
12	BIN AVE 0	
11	CDC Enable	Column Defect Corrector
10	Grey Code Enable	Grey Code data transfer from AFE to FPGA enabled
9	Trigger Marker Line Mode	
8	Trigger Marker Enable	
7		
6	Trigger Arm Enable	
5		
4	AFE 14Bit Data path mode	
3	PPS Strobe Delay Enabled	
2	PPS Shutter Delay Enabled	
1	PPS Interrupt Enabled	
0	Option Board #1 Enabled	

Mode Register #7

Bit	Name	Description
15		
14		
13		
12		
11		
10		
9		
8		
7		
6	TSE Mode	
5	UART master enabled	
4	UART slave enabled	
3	Histogram Equalization Enabled	
2	AE Histogram Detector Enable	
1	AE in IRIS mode	
0	AE in gain mode	

Mode Register #8 (Unused)

Status Register #1

Bit	Name	Description
15	FACT_CRC_ERR	CRC error in factory EEPROM area
14	AE_ERR	Error in auto exposure operation
13	V5_ERR	5V power supply is out of range
12	V12_ERR	12V power supply is out of range
11	VH_ERR	High voltage power supply is out of range
10	VL_ERR	Negative voltage power supply is out of range
9	TDE Frame #	Indicates which of the two TDE frames is being read out
8	DCM Locked	DCM = Digital Clock Manager
7	DCM Timeout	
6	VSYNC Timeout	
5	UART Error	1 = receive buffer overflow
4	WDT Reset	A watchdog timer reset has occurred
3	Normal Power Up	
2	Brownout Reset	A power brownout has occurred and reset the microprocessor
1	Xilinx Configuration Failed	A very bad thing ! (The FPGA could not be configured)
0	WDT Enabled	Watch Dog Timer

Status Register #2

Bit	Name	Description
15	USER_CRC_ERR	CRC error in user EEPROM area
14		
13		
12		
11		
10		
9		
8		
7		
6		
5	AMBER LED	1 = AMBER LED is on
4	RED LED	1 = RED LED is on
3	IBT 1 complete	
2	PIO State Save Failed	PIO = Parallel IO = Communication path from micro to FPGA.
1	ADC B State Save Failed	ADC = Analog to Digital Converter
0	ADC A State Save Failed	

Status Register #3 (1 Tap) #5 (2 Tap) Built In Test Status		
Bit	**Name**	**Description**
15	SNR RN Detector BIT	SNR Right Number of Pixels
14	SNR RSQR Detector BIT	SNR Right Sum of Pixel Squares
13	SNR RSUM Detector BIT	SNR Right Sum of Pixels
12	AF Detector BIT	
11	AE Detector BIT	
10	OSD 2X BIT	
9	OSD 1X BIT	
8	Line Bar BIT	
7	Line Plot BIT	
6	Column Bar BIT	
5	Column Plot BIT	
4	LUT BIT	
3	Column Defect BIT	
2	Pixel Defect BIT	
1	CCD Test pattern BIT	0 = ok, 1 = failure
0		

Status Register #4 (1 Tap) #6 (2Tap) Built In Test Status		
Bit	**Name**	**Description**
15		Not Used
14		Not Used
13		Not Used
12		Not Used
11		Not Used
10	PIO Word Test	
9	PIO Byte Test	
8	LA Detector BIT	Lines Active Per Frame Detector
7	LPF Detector BIT	Lines Per Frame Detector
6	PA Detector BIT	Pixels Active Per Line Detector
5	PPL Detector BIT	Pixels Per Line Detector
4	SNR LMAX Detector BIT	SNR Left Tap Max Value Detector
3	SNR RMAX Detector BIT	SNR Right Tap Max Value Detector
2	SNR LN Detector BIT	SNR Left Number of Pixels
1	SNR LSQR Detector BIT	SNR Left Sum of Pixel Squares
0	SNR LSUM Detector BIT	SNR Left Sum of Pixels

Baud Rate

The Camera link 1.0 specification allows for serial communication at 9600 baud only. The 1.1 specification provides for faster rates.

The RMV camera allows for the setting of the baud rate to one of five rates. This setting can be made for only the current power cycle or for the boot cycle.

The RMV camera allows the user the option of saving the communication speed in the camera EEPROM. This can cause communication with the camera to be lost if the command is not used carefully. Note that only one of the baud rates will be used so that if communication is lost it can be restored by trying the other baud rates.

Once the EEPROM baud rate is set the camera must be re-powered to set the rate.

Quick FAQ's:
- ► The Camera Link specification requires the camera to always start up at 9600 baud.
- ► **DANGER !** The Camera link and external serial port can be forced to start at a different rate. Note that this will disable the communication with your camera from some control applications.
  USE WITH CAUTION !
- ► The baud rate is set to 9600 from the factory.

Serial Commands

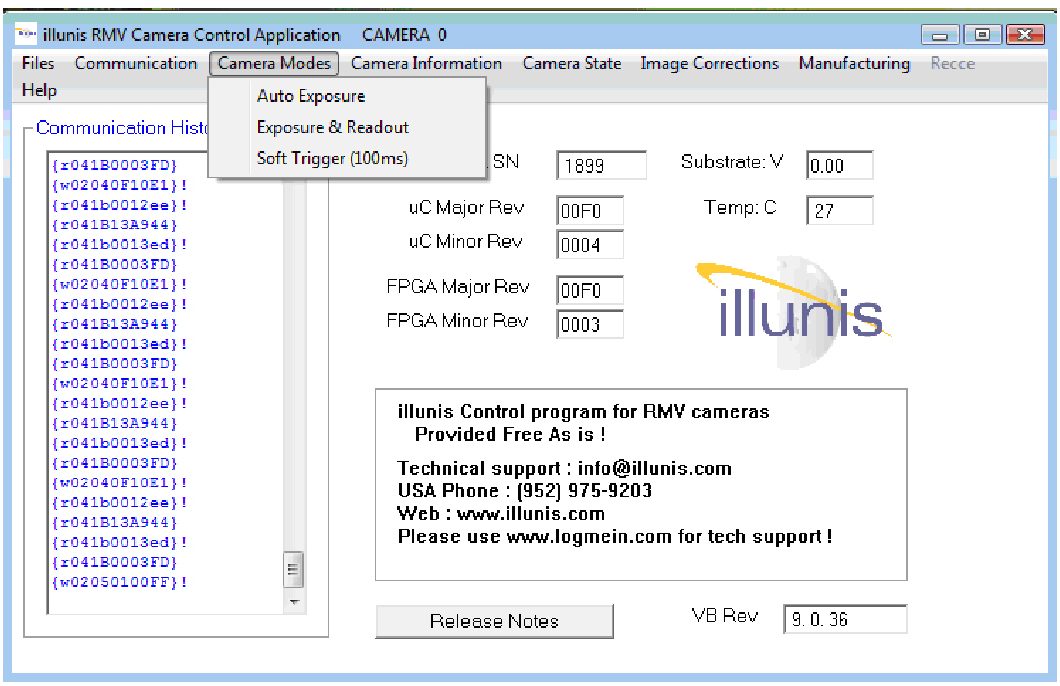
Target	Index	Command	R/W	Description
04	09	Set Current Baud Rate	W	0x0000 = 9600 0x0001 = 19200 0x0002 = 38400 0x0003 = 57600 0x0004 = 115200
04	D2	Set Camera Link Boot Baud Rate (Requires reboot)	R/W	0x0000 = 9600 0x0001 = 19200 0x0002 = 38400 0x0003 = 57600 0x0004 = 115200
04	D3	External Serial Boot Baud Rate (Requires reboot)	R/W	0x0000 = 9600 0x0001 = 19200 0x0002 = 38400 0x0003 = 57600 0x0004 = 115200
04	D0	Power Up	W	Resets camera and powers up circuits

3.6: Graphical User Interface
Overview and installation

Overview

The RMV cameras are feature rich and to some rather complicated to interface. To ease the introduction to the RMV command set and allow easy user control of the cameras illunis has provided a graphical user interface (GUI). The GUI is a visual program that consists of several windows, menus and dialog boxes for each of the many features of the RMV camera.
The GUI is installed using a standard windows installer program available from the illunis web site.

The complete installation and operating instructions for the GUI program are included in the “Quick Start Guide” to RMV cameras. Please contact info@illunis.com or call (USA) 952-975-9203.



Chapter 4: Exposure

Rugged Machine Vision

Overview

The RMV can be programmed to expose images in several different modes. These modes are grouped into two categories, free run modes and triggered modes.
In the free run mode the RMV camera continuously exposes and outputs images.
In the trigger modes the RMV waits for a trigger event, and on the trigger rising edge, then begins a exposure/readout cycle. The RMV exposure modes are:

RMV Exposure Modes	
Mode	**Description**
FRM	**Free Run Mode:** Camera generates all timing signals. Exposure is set by a register that specifies lines of erasure. Trigger signals are ignored.
FRS	**Free Run Synchronize:** Camera generates all timing signals. Exposure is set by a register that specifies lines of erasure. If the trigger is not asserted, then the image readout is halted at the 4th line. When the trigger is asserted the readout resumes. This mode allows multiple free running cameras to be synchronized with the trigger signal. FRS is enabled by selecting FRM and ASYNC RESET.
TPE	**Triggered Program Exposure:** The camera waits in an idle flush state for a trigger rising edge. On the trigger rising edge the photo diode array is erased and an exposure is made based on the value of the Triggered Pulse Delay (TPD) register. When the exposure is complete the image is transferred from the Photo diodes to the CCD, then read out of the CCD and passed to the camera link interface. The camera is reset and waits for another trigger signal to assert.
TME	**Triggered Manual Exposure:** This mode is a superset of the TPE mode and operates exactly the same with the following difference. The exposure is extended by the width of the trigger signal. The programmed exposure is execute at the fall of the trigger pulse. To match the exposure of the image to the trigger pulse width the TPD register should be set to its minimum value (6).
TDE	**Triggered Double Exposure:** This mode is a superset of the TPE mode and operates exactly the same with the following difference. After the first frame is transferred from the Photo Diodes to the CCD a second image is exposed and read out. The exposure of the second frame is equal to the read out time of the first frame. In this mode two frames are exposed and read out for every trigger signal.
TOE	**Triggered Overlap Exposure:** This mode allows overlap of the exposure and readout of the sensor. In TOE mode the assertion of the trigger signal transfers the image data from the photo diodes into the CCD and begins readout. The photo diodes then begin imaging. The time between trigger assertions defines the exposure. The trigger pulse width is not used..

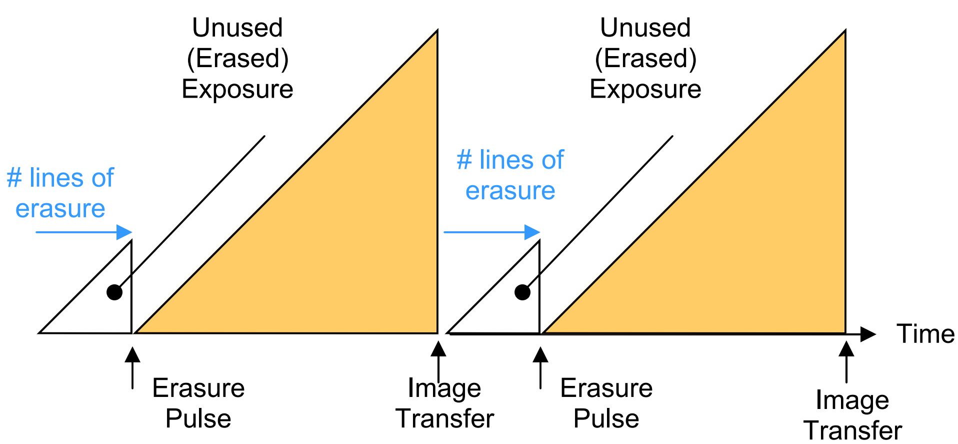
The camera link control signal CC1 is used to implement the trigger function.   The RMV does NOT have a programmable trigger polarity and *the trigger polarity is assumed to be positive.*
In addition on some cameras there is a external trigger source that can be used.

Multiple RMV cameras can by synchronized with the CC1 signal.

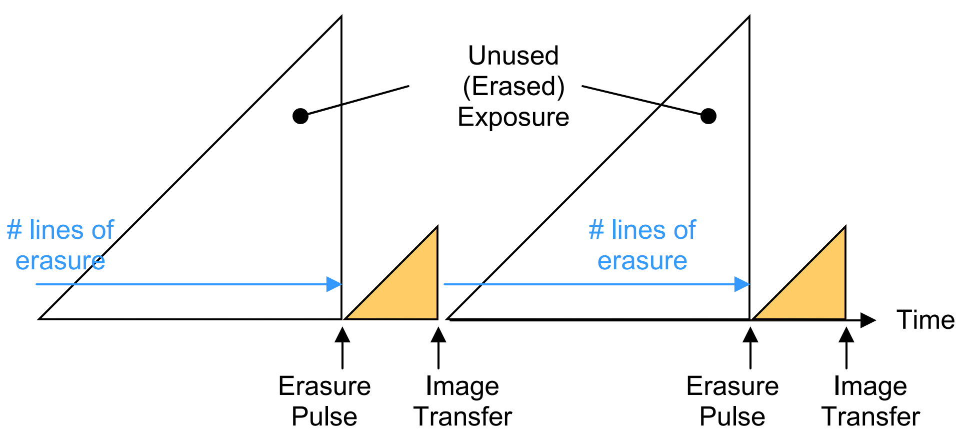
In the trigger mode this is accomplished by sending the same trigger signal to multiple cameras at the same time.

Exposure control is performed differently for free run and trigger readout.

Free Run exposure control is set in lines of erasure. Consider the CCD sensor in free run mode. The sensor is exposing its photodiodes with a new image while at the same time the previous image is being read from the storage CCD. Because of the reading of the previous image the timing of the electronic shutter can only happen during the horizontal line blanking. Thus the electronic exposure can only happen once every line. This results in a free run exposure time resolution of one line time. Now consider that the exposure of the new image starts at the first line of readout and continues until the electronic shutter signal is asserted. The time of the electronic shutter is defined as a line of readout. Thus

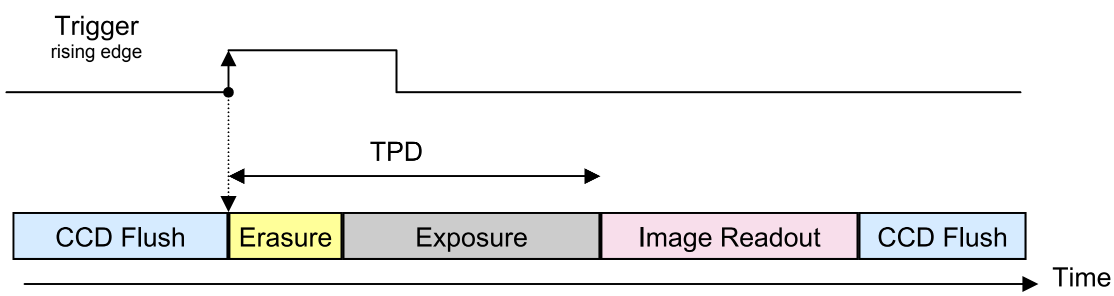


Free Run exposure example: Long exposure

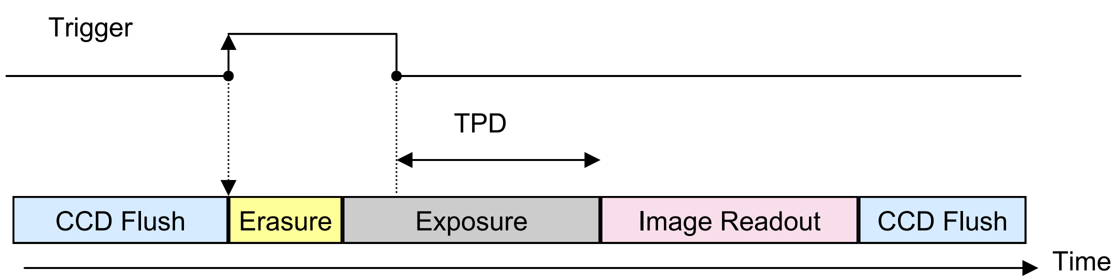


Free Run exposure example:Short exposure

Triggered exposure control is set in pixel clock increments. A special trigger clock in the RMV, equal to the pixel clock divided by 4/16/64/1024 is used to calculate the triggered exposure time. The triggered exposure is set with a register called the Transfer Pulse Delay (TPD). **TPD is the time from the trigger to the transfer of the photodiode image data into the CCD storage area for readout.** In the RMV trigger mode the camera waits for a trigger while simultaneously flushing the internal CCD. When a trigger is detected the TPD counter starts from zero. The TPD counter is used to time the electronic erasure pulse that is used to clear the photo diodes and begin exposing a new image. This electronic erasure pulse requires 6 TPD time periods. (Thus the minimum TPD is 6). The TPD counter is then incremented using the special trigger clock (1/64th the pixel clock) until the TPD counter is equal to the TPD register. When the TPD counter equals the TPD register the image transfer and readout cycles are started.



Triggered exposure example: TPE
TPD determines the exposure



Triggered exposure example: TME
Trigger pulse width plus TPD determines the exposure

Mode interactions:

FRM + ASYNC RESET = FRS (Free Run Synchronized mode)

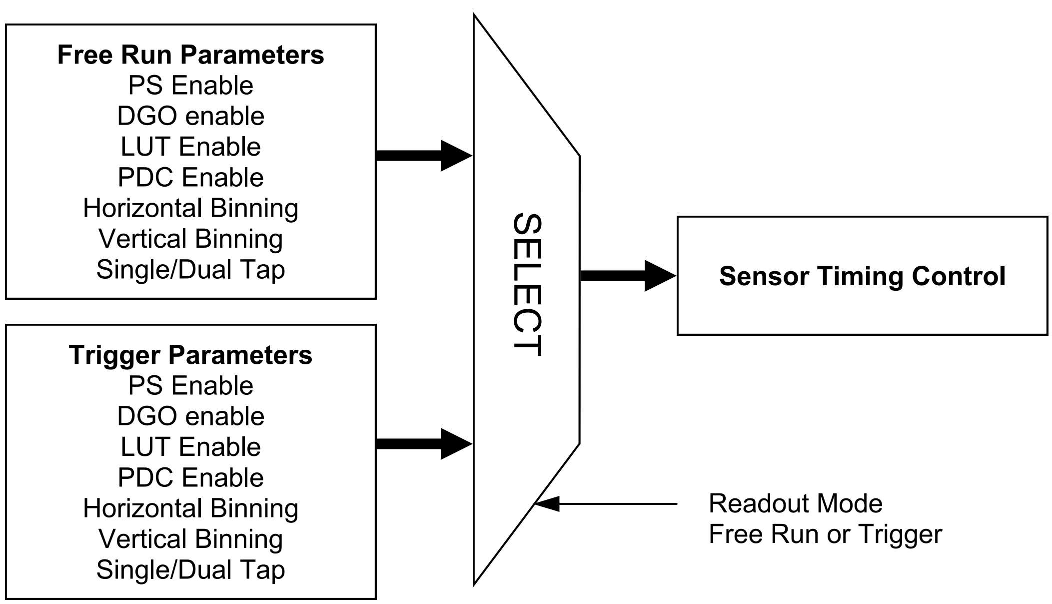
TOE modifies TPE and TME modes

TME exposure time = TPD + Trigger Pulse Width

A special feature of the RMV is a the ability to turn image processing features on and off in the exposure and trigger modes. Each mode has it's own enables for:

RMV Exposure Specific Mode Enables	
Mode	**Description and Example**
PS	**Partial Scan:** The PS mode can be used to increase frame rates for image feature searching. For example the PS mode could be used to search a small number of image lines at a high speed to find printed circuit board fiducials. Once found a full image can be used for inspection.
DGO	**Digital Gain and Offset:** The DGO can be used in the portrait photography example to enhance the live preview mode image contrast (with no effect on the triggered image)..
LUT	**LUT :** The look up tables can be used to apply a gamma function to a live preview and not to the triggered image. This is desirable when a good looking live image is needed but the final image is heavly software processed and only raw image data is needed.
PDC	**Pixel Defect Correction:** The PDC circuit must be disabled in the binning modes.
BINNING	**Binning:** Horizontal and Vertical binning can be specified separately for each mode.

Commands to the camera can specify if the command is to be applied to the free run mode, the trigger mode or common to both modes.



Mode Control Block Diagram

TPD Time Constant

The trigger transfer pulse delay (TPD) is a register that is used to define a triggered exposure. The TPD register is set to an integer value that represents a counter based on a value called the TPD unit time.

The TPD unit time is a programmable clock that is selectable between four different divisors of the master camera pixel clock. The divisors are 4, 16, 64, 1024. The range of divisors allow for very fine control to very long exposures.

For help on this command contact dave@illunis.com

Quick FAQ's:
►If your application requires very short exposures use the TPD clock divisor 4.

►If your application requires very long exposures use the TPD clock divisor 1024.

►Cameras previous to FPGA release E7 used a fixed TPD divisor of 64.

►Note that when using the TPD divisor 1024 the exposure time may be larger than the maximum the exposure detector can measure.

Serial Commands

Target	Index	Command	R/W	Description
02	0E	TPD resolution	R/W	0x0000 = 4 clock periods 0x0001 = 16 clock periods 0x0002 = 64 clock periods 0x0003 = 1024 clock periods

$$TPD_{time} = \text{Pixel Clock Period} * TPD_{unit\ time}$$

RMV TPD Time constants			
Pixel Clock	**20Mhz**	**30Mhz**	**40Mhz**
Pixel Period	0.050us	0.0333us	0.025us
TPD unit time (4 periods)	0.200us	0.1333us	0.100us
TPD unit time (16 periods)	0.800us	0.5333us	0.400us
TPD unit time (64 periods) default	3,200us	2.1333us	1.600us
TPD unit time (1024 periods)	51.2us	34.132us	25.6us
Min TPD time (TPD = 1, 4 periods)	0.200us	0.1333us	0.100us
Max TPD time (TPD = 65535, 1024 periods)	3,35 sec	2.23 sec	1.67 sec

4.1.1: Exposure: Free Run Modes

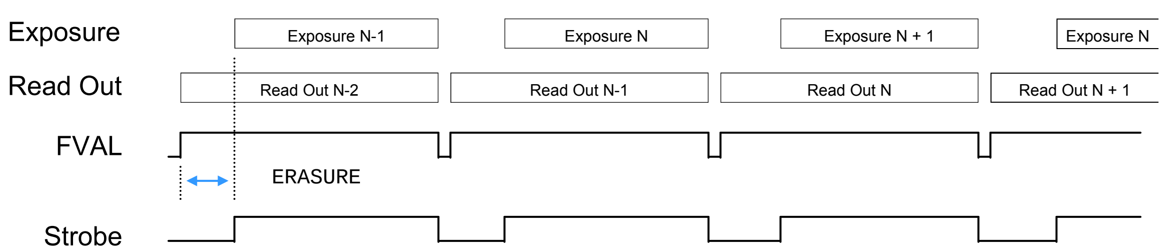
FRM: Free Run Mode

In Free Run Mode the camera generates all timing signals to the CCD and to the camera link port. The trigger signal is ignored. The exposure is set with the ERASURE register A minimum ERASURE value of 1 results in the maximum exposure time. The maximum ERASURE value, dependent on the CCD used, sets the minimum exposure time.

Quick FAQ's:
- ►FRM is sometimes called continuous mode.
- ►In FRM the exposure and readout are overlapped.
- ►FRM exposure is set in units of line timing
- ►The strobe signal can be used to determine frame timing.
- ►The exposure detector can be used to measure the exact exposure in free run mode.

Serial Commands

Target	Index	Command	R/W	Description
04	03	Readout Mode Select	W	**0x0000 = Free Run Exposure**
02	0A	Free Run Erasure	R/W	Sensor Dependant
02	02	Set Free Run ms	W	Set FR time in milliseconds * 100
02	03	Set Free Run us	W	Set FR time in us
02	02	Get Free Run ms	R	Return actual time in milliseconds * 100
02	03	Get Free Run us	R	Return actual time in us (0xFFFF = to large).



Free Run Modes

Long V-Count

A Special operating mode of FRM is the long V-count. In this mode the vertical counter is not terminated at the end of the sensor rows but at the value specified in TPD. This allows the free run time to be extended, thus lowering the frame rate and allowing for longer exposures and custom frame rates. The electronic exposure and long V-count are allowed up to 65535 (0xFFFF).

Quick FAQ's:
- ►Long V-count is very useful for custom frame rates needed in special applications.
- ►Long V-count works with auto exposure.
- ►The range is up to 0xFFFF or 65535
- ►Electronic exposure functions across the entire range of Long V-count.

Serial Commands

Target	Index	Command	R/W	Description
04	04	0x0013	W	Enable Long V-count
04	4	0x0014	R/W	Disable Long V-count

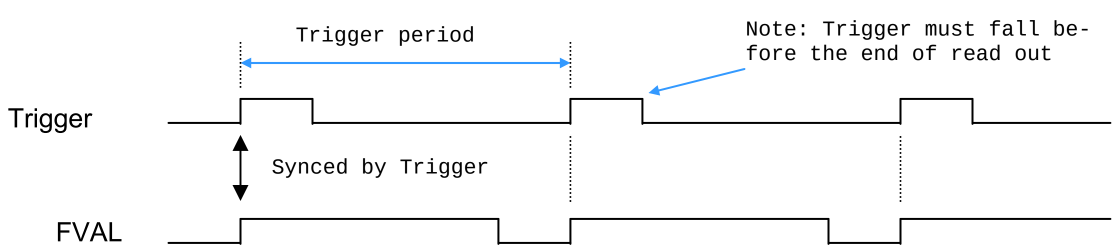
FRS: Free Run Synchronize Mode

In Free Run Sync mode the camera generates all timing signals to the CCD and to the camera link port as in FRM with the following exception: After the image is transferred into the interline storage area of the CCD, the camera waits for the trigger to assert. Thus the camera waits for a SYNC signal - provided by the trigger - and thus allows several cameras to be slaved to the trigger signal.

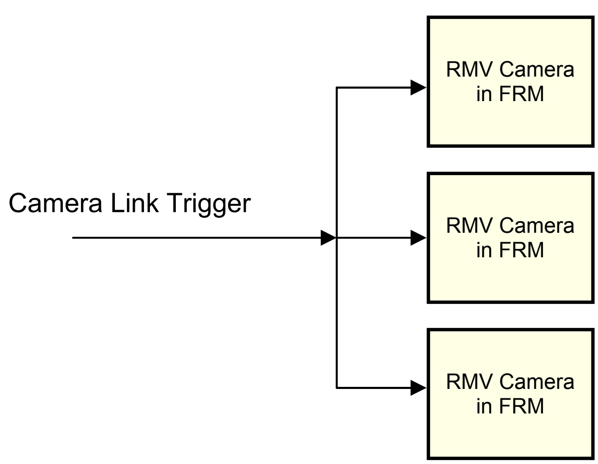
Quick FAQ's:
- FRS is used to sync free running cameras.
- Cameras can be synced to one pixel clock period.
- Any number of cameras can be synchronized.
- The strobe signal can be used to determine frame timing.
- The strobe signal can be found on the RMV power connector and is a 3.3V LVTTL signal.
- FRS mode works with Auto exposure in rev E9

Serial Commands

Target	Index	Command	R/W	Description
04	03	Readout Mode Select	W	**0x0004 = Free Run Synchronize** (Note ASYNC reset will work)



FRS Example: To Synchronize multiple free running cameras connect the triggers to the same source and set the cameras to FRS mode Not that the trigger timing is very critical and that the trigger period must be slightly greater than the free run frame in order to sync at the maximum possible rate.



Set Free Run Exposure Time

The free run exposure time is set In lines of erasure. The resolution of the exposure is in horizontal line times. Two commands are provided for calculating the free run time from a specified time variable (milliseconds or microseconds). **The closest available time is selected and set in the internal time variable.** The maximum free run time is dependent on the sensor, readout mode, and pixel clock speed. The millisecond variable is set as ms*100 to give more resolution to the command. This results in a maximum possible exposure of 655ms although the value is sensor dependent.

Quick FAQ's:

- ▶The strobe signal can be found on the RMV power connector and is a 3.3V LVTTL signal.
- ▶Minimum exposure time is set by the photodiode transfer to vertical CCD clock sequence.
- ▶Maximum exposure time is set by the sensor size and line timing.
- ▶**Note**: The exposure time must be resent if you change single/dual tap mode.

Serial Commands

Target	Index	Command	R/W	Description
02	02	Set Free Run ms	W	Set FR time in milliseconds * 100
02	03	Set Free Run us	W	Set FR time in us
02	02	Get Free Run ms	R	Return actual time in milliseconds * 100
02	03	Get Free Run us	R	Return actual time in us (0xFFFF = to large).

Example:

Set free run time to 10 ms

{w020203E815} 0x3E8 = dec 1000 = 10ms * 100

{w02032710C9} 0x2710 = dec 10000us = 10ms

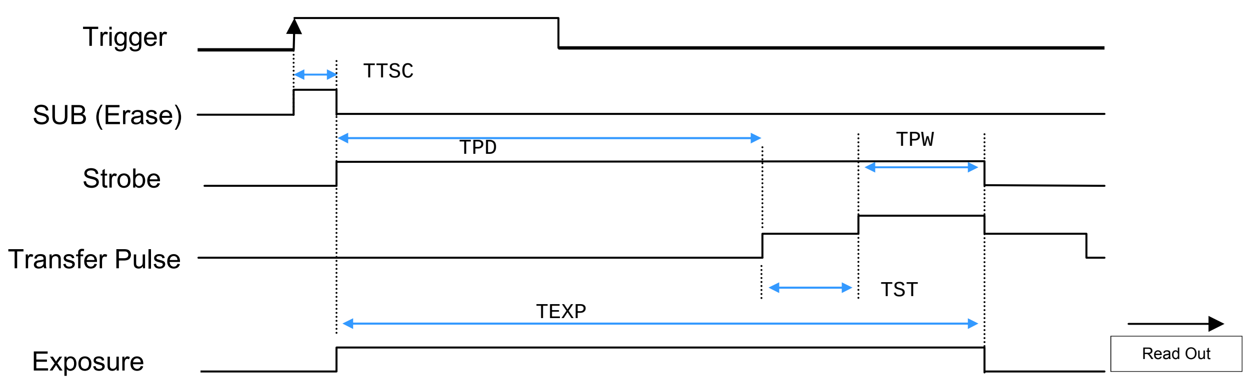
TPE: Triggered Programmed Exposure

TPE mode uses the trigger pulse to start a programmed expose/readout cycle. The exposure is set by the Transfer Pulse Delay (TPD) register. The TPD is set in increments of 4,16,64 or 1024 pixel clock periods.

Quick FAQ's:
- ►Use the TPE mode to control exposure within the RMV camera.
- ►The rising edge of the trigger pulse determines the beginning of exposure.
- ►Multiple Cameras with the same trigger can be slaved together for very exacting applications
- ►The strobe signal can be found on the RMV power connector and is a 3.3V LVTTL signal.

Serial Commands

Target	Index	Command	R/W	Description
04	03	Readout Mode Select	W	**0x0001 = Trigger Program Exposure**
02	04	Transfer Pulse Delay	R/W	0x0007 to 0xFFFF
04	1B	Transfer Pulse Width	R	0x0004 = TPW (Preset at factory)
02	00	Set Trigger ms	W	Set TR time in milliseconds * 100
02	01	Set Trigger us	W	Set TR time in us
02	00	Get Trigger ms	R	Return actual time in milliseconds * 100
02	01	Get Trigger us	R	Return actual time in us (0xFFFF = to large).
02	0E	TPD resolution	R/W	0x0000 = 4 clock periods 0x0001 = 16 clock periods 0x0002 = 64 clock periods 0x0003 = 1024 clock periods



TME: Triggered Manual Exposure

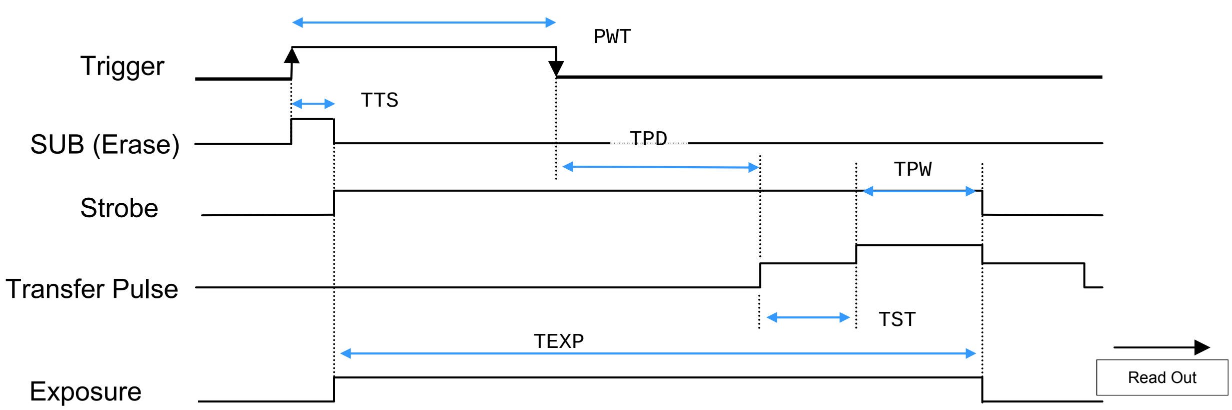
TME mode uses the trigger pulse to start a programmed expose/readout cycle. The exposure is set by the width of the trigger pulse and Transfer Pulse Delay (TPD) register. TPD should be set to its minimum value so that the trigger pulse width controls the exposure. TME mode is the same as TPE mode with the exception that the exposure is extended by the trigger pulse width.

Quick FAQ's:

- ► Use the TME mode to control exposure with a camera link capture device's trigger signal.
- ► The rising edge of the trigger pulse determines the beginning of exposure.
- ► The falling edge of the trigger pulse starts a TPE cycle. Set TPD to a its minimum value.
- ► The strobe signal can be found on the RMV power connector and is a 3.3V LVTTL signal.

Serial Commands

Target	Index	Command	R/W	Description
04	03	Readout Mode Select	W	**0x0002 = Trigger Manual Exposure**
02	04	Transfer Pulse Delay	R/W	0x0007 to 0xFFFF
04	1B	Transfer Pulse Width	R	0x0004 = TPW (Preset at factory)
02	00	Set Trigger ms	W	Set TR time in milliseconds * 100
02	01	Set Trigger us	W	Set TR time in us
02	00	Get Trigger ms	R	Return actual time in milliseconds * 100
02	01	Get Trigger us	R	Return actual time in us (0xFFFF = to large).
02	0E	TPD resolution	R/W	0x0000 = 4 clock periods 0x0001 = 16 clock periods 0x0002 = 64 clock periods 0x0003 = 1024 clock periods



TDE: Triggered Double Exposure

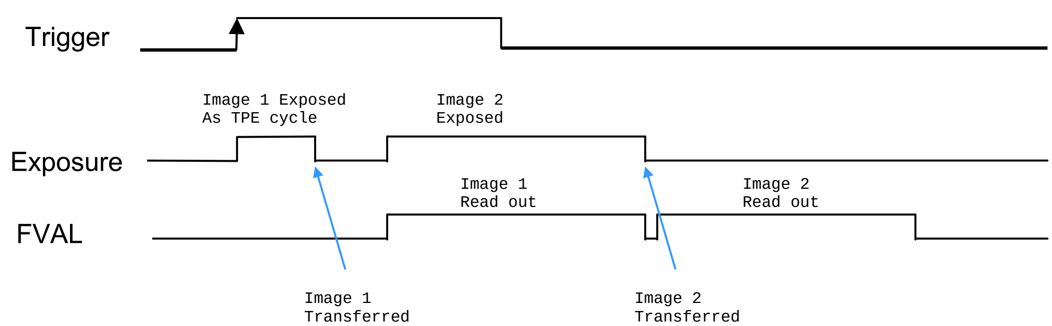
TDE mode uses the trigger pulse to capture two images in rapid succession. This is accomplished by capturing the first image in the Photo Diodes, transferring this image to the vertical CCD, and then capturing a second image in the Photo Diodes. The first image is read from the CCD as the second image is exposed. The second image is then transferred and read from the CCD. The second image exposure is fixed to the readout time of the first image.

Quick FAQ's:

- ►Use the TDE mode with external illumination control to grab two closely timed images.
- ►The rising edge of the trigger pulse determines the beginning of first exposure.
- ►The strobe signal can be used to determine frame timing.
- ►The strobe signal is only valid for the first frame.
- ►The Transfer Pulse Width (TPW) can be used to minimize the frame to frame timing.

Serial Commands

Target	Index	Command	R/W	Description
04	03	Readout Mode Select	W	**0x0003 = Triggered Double Exposure**
02	04	Transfer Pulse Delay	R/W	0x0007 to 0xFFFF
04	1B	Transfer Pulse Width	R	0x0004 = TPW (Pre-set at factory)
02	00	Set Trigger ms	W	Set TR time in milliseconds * 100
02	01	Set Trigger us	W	Set TR time in us
02	00	Get Trigger ms	R	Return actual time in milliseconds * 100
02	01	Get Trigger us	R	Return actual time in us (0xFFFF = to large).
02	0E	TPD resolution	R/W	0x0000 = 4 clock periods 0x0001 = 16 clock periods 0x0002 = 64 clock periods 0x0003 = 1024 clock periods



TOE: Triggered Overlap Exposure

TOE mode uses the trigger pulse to define a overlapped exposure and readout sequence. The TPD must be set to 0x0006. The TOE mode modifies the TPE and TME modes so no SUB (electronic erasure) pulse is generated. This effectively creates a overlapping exposure and readout. The time between trigger pulses determines the exposure (time). Note that the STROBE signal is not valid in TOE mode.

To use TOE mode both TPE/TME and TOE must be activated.

Quick FAQ's:

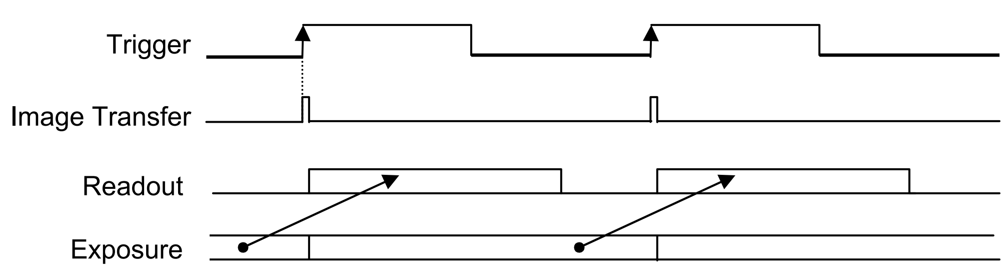
►Use the TOE mode to maximize triggered readout speed. Because the readout is overlapped with the exposure the triggered mode can run at nearly the speed of free run exposure.

►The rising edge of the trigger pulse determines the beginning of image readout and exposure of the next image.

►An initial frame must be read to start a sequence.

Serial Commands

Target	Index	Command	R/W	Description
04	03	Readout Mode Select	W	**0x000b = Trigger Overlap Exposure enable**
04	03	Readout Mode Select	W	**0x000c = Trigger Overlap Exposure disable**
02	04	Transfer Pulse Delay	R/W	0x0007 to 0xFFFF
04	1B	Transfer Pulse Width	R	0x0004 = TPW (Preset at factory)
02	00	Set Trigger ms	W	Set TR time in milliseconds * 100
02	01	Set Trigger us	W	Set TR time in us
02	00	Get Trigger ms	R	Return actual time in milliseconds * 100
02	01	Get Trigger us	R	Return actual time in us (0xFFFF = to large).



4.2.5: Exposure: Trigger Modes
Set Trigger Exposure Time

The trigger run exposure time is set in increments of the TPD Period. This unit of time is called the Transfer Pulse Delay (TPD).

Two commands are provided for calculating the triggered exposure time from a specified time variable (milliseconds or microseconds). The closest available time is selected and set in the internal time variable. The maximum triggered time is dependent on the pixel clock speed. The millisecond variable is set as ms*100 to give more resolution to the command. This results in a maximum possible exposure of 65535 TPD units.

Quick FAQ's:

- ▶The strobe signal can be found on the RMV power connector and is a 3.3V LVTTL signal.
- ▶Minimum exposure time is set by the physics of the photodiode transfer to vertical CCD clock sequence. The electronics can be set for any exposure downto zero.
- ▶Maximum exposure time is set by the TPD period and the maximum TPD register value (65535).

Serial Commands

Target	Index	Command	R/W	Description
02	00	Set Trigger ms	W	Set TR time in milliseconds * 100
02	01	Set Trigger us	W	Set TR time in us
02	00	Get Trigger ms	R	Return actual time in milliseconds * 100
02	01	Get Trigger us	R	Return actual time in us (0xFFFF = to large).
02	0E	TPD resolution	R/W	0x0000 = 4 clock periods 0x0001 = 16 clock periods 0x0002 = 64 clock periods 0x0003 = 1024 clock periods

4.2.6: Exposure: Trigger Modes
Software Controlled Trigger

This command forces an internal trigger from a software command. The soft trigger pulse has a width in us as specified in the data field. The range is 1 to 65535 ms (65sec). The timing is approximate due to the inaccuracies in the microprocessor time function. The exposure time is set with the TDP register in TPE mode. The set trigger high/low can be used to create an arbitrary long exposure. The software trigger is logically OR'd with the CL hardware trigger so you must disable the hardware trigger on your capture card for this to function correctly.

Quick FAQ's:

- ▶Minimum exposure time is set by the photodiode transfer to vertical CCD clock sequence.
- ▶Maximum exposure time is set by the maximum register value (65535).
- ▶Use an initlizing software trigger to reset the camera.
- ▶NOTE: Beware of timeout conditions when using long exposures !
- ▶NOTE: The trigger input must be set to CL for the software trigger to work !

Serial Commands

Target	Index	Command	R/W	Description
02	05	Soft Trigger	W	Issue a soft trigger with width in ms
02	06	Soft Trigger high	W	Sets trigger high
02	07	Soft Trigger low	W	Sets trigger low

Trigger Substrate Pulse Delay

The trigger substrate delay (TSUBD) pulse is useful in applications where a very powerful flash is used. Because a very bright flash will overpower the VCCD light shield and create unwanted smear the TSUBD is used to delay the photo diode erasure pulse (Substrate Pulse).

If the VCCD is clocked during a very bright flash then the sensor will contain smear within the VCCD. The TSUBD allows for the VCCD flush to stop before the flash thus preventing image smear (from the flash).

Quick FAQ's:

► Use the TSUBD with applications that have very tight timing and very bright flash exposures.

► The TSUBD time units are the same as TPD.

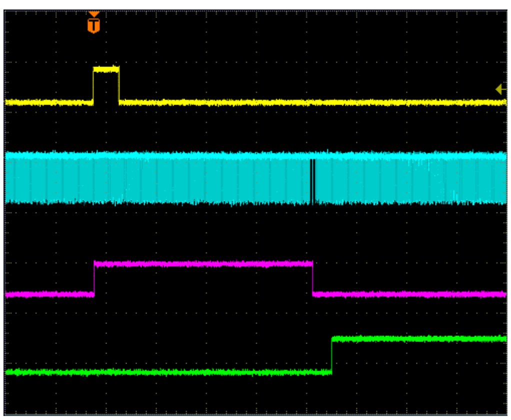
► The substrate pulse is used to erase the photo diodes for the beginning of exposure.

► The default for normal operation of TSUBD is a register value of 0x0001

► TheTSUBD must be zero for TME mode to function.

Serial Commands

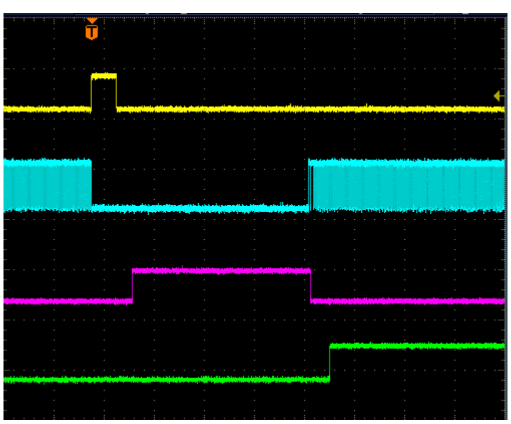
Target	Index	Command	R/W	Description
02	0B	SUB Delay	R/W	Default = 0x0001
02	0C	Triggered VCCD on	W	VCCD clocks during triggered exposure
02	0D	Triggered VCCD off	W	No VCCD clocks during triggered exposure



Normal Triggered Image

This scope plot shows a normal triggered image where exposure starts at the trigger and ends at the interline transfer. The VCCD is clocked throughout the exposure to minimize dark current buildup in the VCCD.

Yellow = Trigger, Blue = VCCD Clocks, Red = Exposure strobe, Green = FVAL



Triggered Image with VCCD off and TSUBD

This scope plot shows a triggered image where exposure is delayed from the trigger by the TSUBD register value (and ends at the interline transfer). The VCCD is stopped throughout the exposure to eliminate smear of the image in the VCCD.

Yellow = Trigger, Blue = VCCD Clocks, Red = Exposure strobe, Green = FVAL

4.3: Exposure: Asynchronous Reset

The trigger modes may be used in a async reset where the RMV is operated in a free run mode and is reset by the trigger signal.

In this mode the camera runs as if in FRM and waits for a trigger.

Once the trigger signal is recognized the camera “resets” by flushing the internal CCD’s and erasing the photo diodes. The selected triggered image is then exposed and readout.

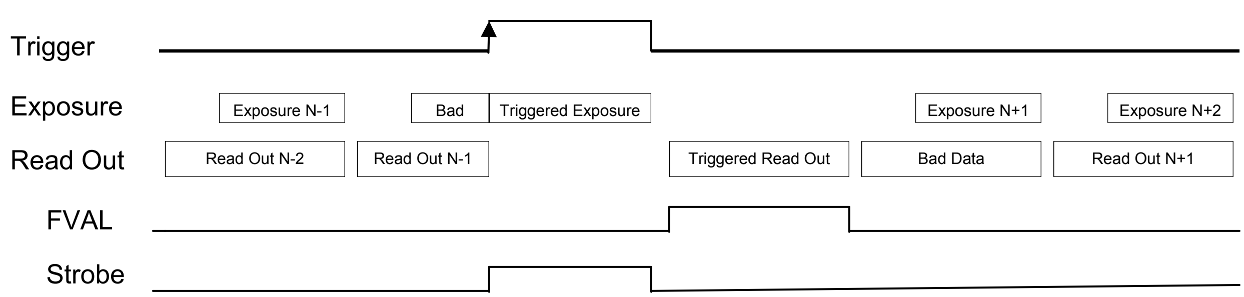
The camera then returns to FRM (free run mode).

Quick FAQ’s:

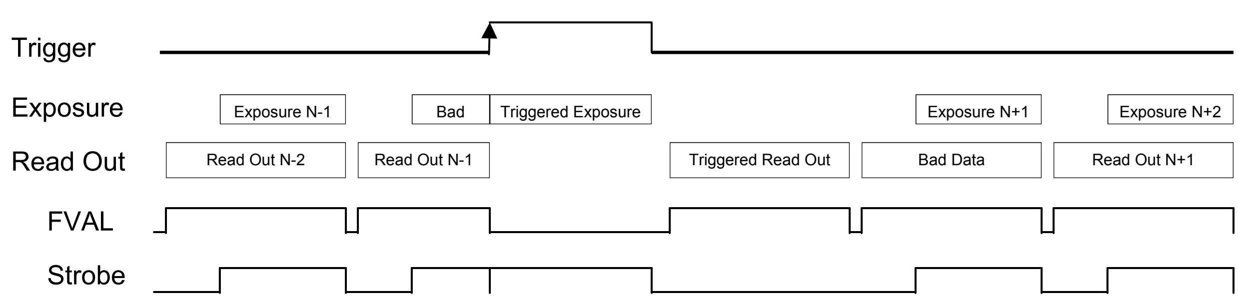
- ►Some camera manufactures call their trigger mode Async reset as they do not have different trigger and free run timing.
- ►**If the Async Reset mode is active in free run mode then the Free Run Synchronize mode is active.** The camera will sync to the trigger signal.
- ►The RUN VALS option controls the output of FVAL and LVAL during async reset mode.
- ► Async Reset mode and Runs Valid disabled are useful with auto exposure to allow the AE to run and still allow the use of triggered images.
- ►The strobe signal can be used to determine frame timing.

Serial Commands

Target	Index	Command	R/W	Description
04	05	Readout Mode Select	W	**Async Reset Enabled**
04	06	Readout Mode Select	W	**Async Reset Disabled**
04	07	Readout Mode Select	W	**Runs Valid Enabled**
04	08	Readout Mode Select	W	**Runs Valid Disabled**



Async Reset Mode with Run Valid Disabled



Async Reset Mode with Run Valid Enabled

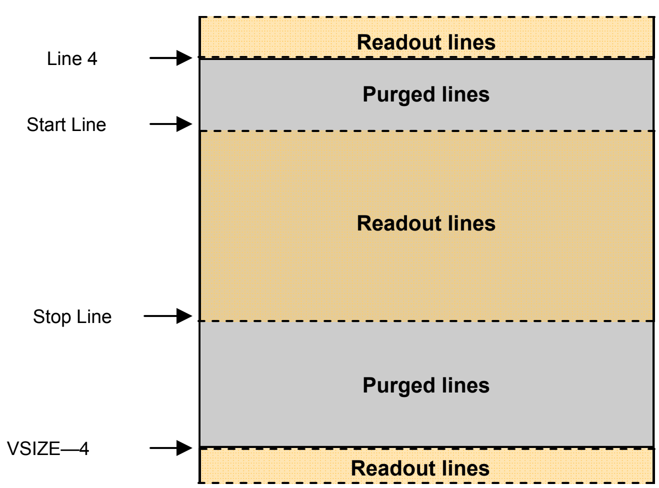
4.4: Exposure:
Partial Scan

Partial Scan mode is used to read a selected number of rows from the CCD. Using the fast dump gate feature of the Truesense Imaging Interline Transfer sensors the PS mode dumps or purges the lines before the start line. Then the lines between the start line and the stop line are read out. Finally the lines after the stop line are purged. Partial scan can be used to increase the frame rate by only reading the lines of interest to an application. There are separate PS enables for free run and trigger modes.

Quick FAQ's:
- ►PS purges unwanted lines of video data.
- ►The stop line must be greater than the start line.
- ►PS of 1/2 the lines of the sensor does not result in 2X the frame rate bacause the purged lines require some time for the purge.
- ►CCD's have non-visable lines that can be selected for purging in the PS mode.

Serial Commands

Target	Index	Command	R/W	Description
04	04	Mode Register	W	**0xM003 = Enable Partial Scan**
04	04	Mode Register	W	**0xM004 = Disable Partial Scan**
M = 0: Common—both, M = 8: Free Run only, M = 4: Trigger only				
04	0A	PS Start Line	R/W	Sensor Dependent
04	0B	PS Stop Line	R/W	Sensor Dependent. (> Start Line)



Partial Scan line selection are readout area

Binning

BINNING uses the CCD sensor to combine adjacent pixels and lines to effectively create larger pixels. The RMV can bin video data independently in both horizontal and vertical modes. Vertical binning merges the charge from adjacent lines on the CCD and creates a composite line in the horizontal shift register on the CCD. This binned data is then read out as a standard line. Vertical binning can be performed in 1 to 32 line increments. Special care must be taken when binning very bright images as the charge in the horizontal shift register can overflow and cause image artifacts. Horizontal binning is performed as digital summation within the FPGA. There is no speed difference between digital and analog binning. Horizontal binning can be performed in 1 to 16 pixel increments. Your capture device must qualify the video data with the DVAL signal for horizontal binning to function. The H-bin math sums the pixel data. You can use the bin data average mode to average the binned pixel data. This will reduce noise and increase the dynamic range of the camera.

Quick FAQ's:

- ►Binning can be independently set for any horizontal and vertical combination.
- ►Horizontal binning in and two channel camera link data modes do not function in all modes.
- ►Vertical binning can overload the HCCD in bright images.
- ►Binning can create super pixels in many sizes.
- ►Vertical binning will increase the power consumption of the camera.
- ►Vertical binning increases the frame rate. 2X vertical binning is does not increase the frame rate by 2X as some time is needed to sum the image.
- ►horizontal binning can be set to sum or to average by using the divide function.

Serial Commands

Target	Index	Command	R/W	Description
04	04	Mode Register	W	**0xM000 = Enable Bin**
04	04	Mode Register	W	**0xM002 = Disable Bin**
M = 0: Common—both, M = 8: Free Run only, M = 4: Trigger only				
04	28	Trigger Mode V Bin	R/W	Values 1 to 32
04	29	Trigger Mode H Bin	R/W	Values 1 to 16
04	2A	Free Run Mode V Bin	R/W	Values 1 to 32
04	2B	Free Run Mode H Bin	R/W	Values 1 to 16
04	52	Bin data average mode	R/W	0x0000 = Sum binned horizontal pixel data 0x0001 = Divide sum by 2 0x0002 = Divide sum by 4 0x0003 = Divide sum by 8

Binning Example: Multi Spectral imaging

In a multi spectral imaging (MSI) application several camera are used, each with a different optical filter. Images from each of the cameras are processed and merged. Examples of the MSI are vegetation detection and identification. Since MSI used optical filters of various wavelengths, the QE response of the sensor at these wavelengths will vary. To improve image brightness binning is used.

The RMV allows for independent binning in the horizontal and the vertical directions. The horizontal binning can be set from 1 to 16 pixels. The vertical binning can be set from 1 to 32 lines. Vertical binning is performed on chip in the HCCD and horizontal binning is performed as a digital summation of pixels with overflow checking.

The RMV can bin pixels in any shape such as 3x7 or 9x14. Please note that when the RMV is operating in Camera Link dual channel mode some horizontal binning modes are not available. This is due to the fact that the DVAL signal Is used in horizontal binning and the DVAL cannot distinguish between the active/inactive pixels on the two channels. DVAL is only valid for both pixels on the dual channel output. If this is a problem then use the single channel Camera Link readout mode.

Auto Exposure: Overview

The RMV camera incorporates an auto exposure (AE) algorithm that allows the camera to automatically adjust exposure (and gain) for changing light levels. The AE uses the AED detector (*section 6.1*) to measure the brightness of an image by summing the pixels within a region of interest called the AED window. The AE algorithm compares the image brightness with a user defined minimum and maximum brightness set-point. If the image is brighter than the maximum the AE algorithm will reduce the exposure or gain. If the image is darker than the minimum the AE algorithm will increase the brightness or gain.

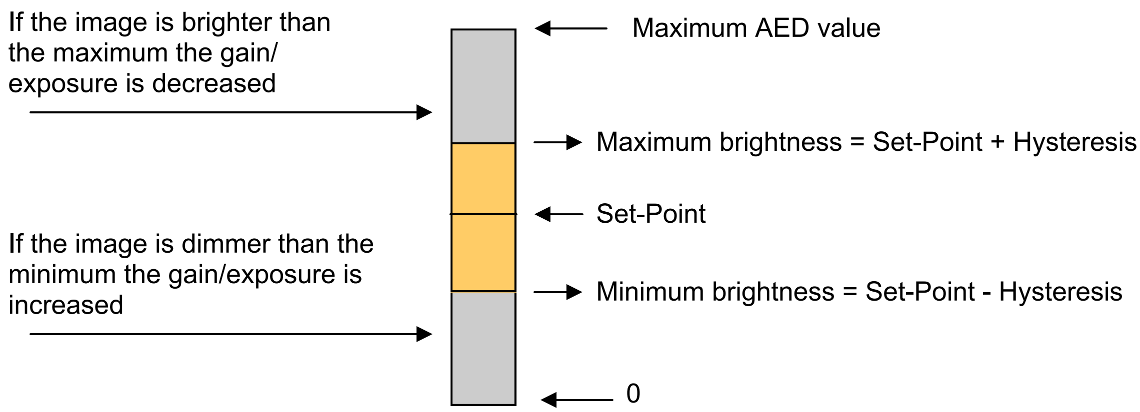


Diagram of AED value vs. Set-Point and Hysteresis

The AE algorithm can run in either gain mode or exposure mode. Gain mode is used if the exposure reaches the user defined maximum exposure. At the point the AE is at maximum exposure it will switch to gain mode and increase the digital camera gain to attempt to brighten the image. At the limits of the gain and exposure modes the AE will set internal mode bits that indicate to the user that an external Iris should be opened or closed. If the user desires to disable gain or exposure mode they only need set the minimum and maximum values for that mode to the same value.

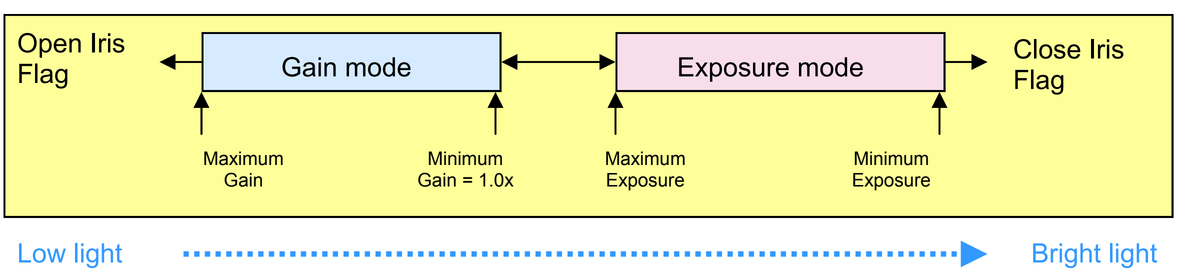


Diagram of exposure/gain modes and iris flags

Auto Exposure: Overview continued

The AE algorithm provides variables for the following:

Setting	Comment
• Minimum digital gain :	Usually set to 1.0x
• Maximum digital gain :	Limited by noise requirements
• Minimum exposure:	Limited my smear requirements
• Maximum exposure:	Motion blur sets maximum
• Set-Point:	Target image brightness
• Hysteresis:	Dead zone around set-point
• AE Detector:	Last Frame Brightness
• AED Average:	AED Average of previous frames.
• AE VSYNC count:	Frame spacing between AE calculations
• AE Detector (AED) window:	ROI on image to measure brightness
• Deterministic AE (Fast):	Calculates next exposure/gain.
• Iterative AE (Slow):	Steps to next exposure/gain.
• Exposure and gain denominator	Used to determine iterative step size
• On Screen Display:	Overlays AE data on image.
• Predefined Recce modes:	Easy setup.

The AE algorithm calculates a new exposure, from the previous exposure, the set-point and the AED value. One of two methods for the new exposure calculation can be used. The first method is an iterative algorithm that uses the following equation:

NEW_EXPOSURE = CURRENT_EXPOSURE—(AED-SETPOINT) / EXP_DENOMINATOR
NEW_GAIN = CURRENT_GAIN—(AED-SETPOINT) / GAIN_DENOMINATOR

In this algorithm the set-point is subtracted from the detector and divided by a scaling factor (denominator). This results in a calculated step that is applied to the exposure. The denominator value determines the step size. Setting the denominator to a larger number will reduce the step size and allow for a slower AE tracking. Reducing the denominator will increase the step size and increasing the AE tracking. However note that at some point, reducing the denominator the AE algorithm will be come un-stable.

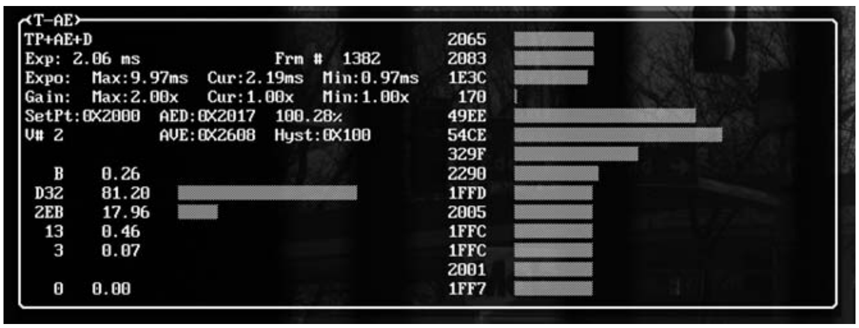
Iterative AE algorithm On Screen Display (Time Version)

4.6: Exposure:
Auto Exposure: Overview continued

The second method is an deterministic algorithm that uses the following equation:

NEW_EXPOSURE = CURRENT_EXPOSURE * (SETPOINT/ AED)
NEW_GAIN = CURRENT_GAIN * (SETPOINT/ AED)

In this algorithm the AE attempts to adjust to the change in light in a single step. The AE is changed by the ratio of the set-point to the detector. If the maximum/minimum of the gain/exposure limits are met by the ratio, then another step will be required to meet the correct exposure/gain setting



Deterministic AE algorithm On Screen Display (Time version)

The AED window can be used in a small or large mode. The small mode is used for AED windows under 1Mega pixel in size. The large mode can be used for AED windows up to 16 million pixels in size. The AE Detector is a simply the sum of the pixels within the AED window. The AED set-point is a arbitrary number compared to the AED. As the AED window changes the maximum value of the AED will change. Set-point should change with it. Set-point is determined by the AED window size and User preference.

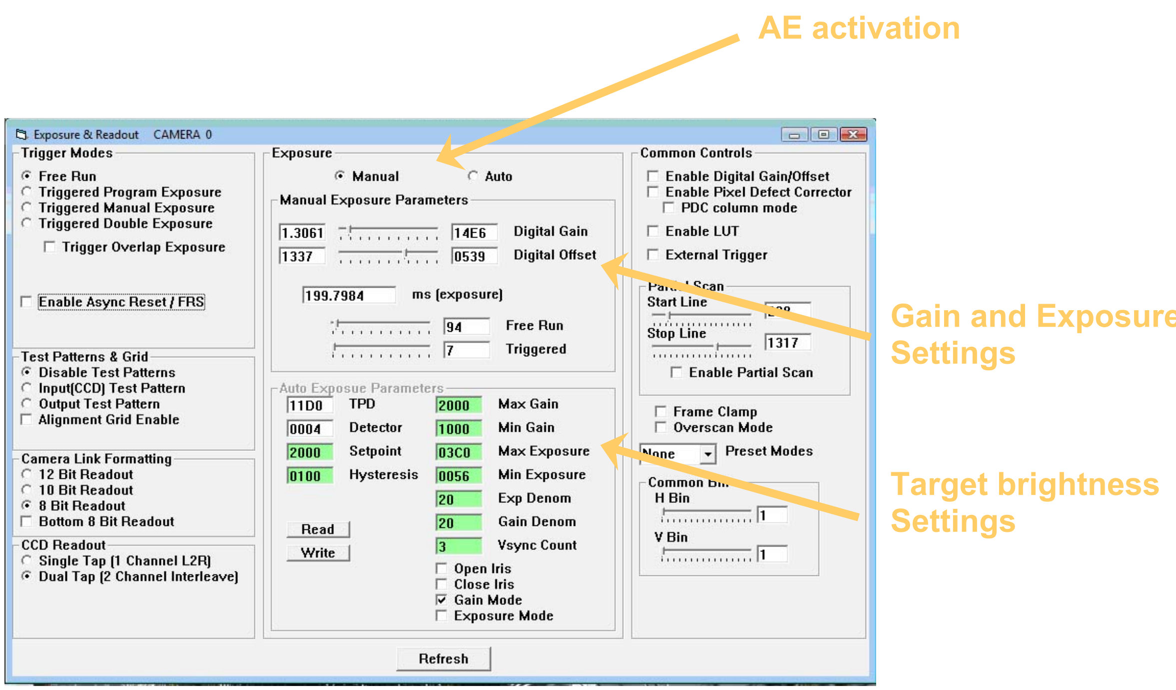
There are two major firmware versions of the AE algorithm. To determine the release version you can read more register 5, bit 15. If this bit is set then you have the new time-based algorithm.

The first release was based on primarily the free run mode and uses the free run erasure register as the basis for setting exposure values. The minimum and maximum exposure limits are set in units of erasure (not a simple concept). This first pass AE algorithm did not operate in trigger mode and required an extensive knowledge of the camera operation.

The second release of the AE algorithm was a complete rewrite and uses time as the basis for all exposure calculations. The time units used are 16bit hexadecimal numbers that indicate time in micro seconds x 10. Thus a time base number 0x3E8 = 1000 (decimal) = 10000 micro seconds = 10.00 milliseconds. This provides for a exposure range up to 0xFFFF = 65535 (decimal) = 65.535 milliseconds. These time values are the same those used in the SetFreeRunTime and SetTriggeredTime commands. The new algorithm also supports the binning modes and partial scan modes (but not both at the same time).

Auto Exposure: Overview continued

The illunis GUI program can be used to setup and explore the AE algorithm. The Exposure and Readout dialog box contains the controls needed to activate and set the AE algorithm parameters.



Exposure and Readout Dialog: AE controls

In this example the AE is setup for the following:

MaxGain = 0x2000 = 2.0x maximum gain
MinGain = 0x1000 = 1.0x minimum gain
MaxExposure = 0x3F1 = 1009 dec = 10.09 ms maximum exposure
MinExposure = 0x068 = 104 dec = 1.04 ms minimum exposure

4.6: Exposure:
Auto Exposure (Time Base)

Auto Exposure mode automatically adjusts the brightness of the image through exposure and gain control. The limits of gain and exposure can be set. The AE algorithm uses the AE detector window to measure the brightness of the image. If the maximum exposure is reached the camera sets a status bit to indicate the iris be opened. There are two counter modes, a smaller mode for windows up to 1Mega pixel and a larger mode for windows up to 16 Mega pixels. The larger counter can cover the entire active area of the RMV-11002.

This function is quite complicated.
For help contact dave@illunis.com.

Quick FAQ's:
- ▶The AE algorithm adjusts both exposure and gain to control the image brightness.
- ▶The limits of minimum and maximum gain can be set. This allows for control of noise .
- ▶AE does work in TPE mode, it does not work in TME, TOE or TDE modes.
- ▶AE uses digital gain (analog gain is fixed).
- ▶The exposure limits are set in us * 10 = ms / 100
- ▶Note: In free run mode (FRM) the max and min exposures are checked and reset to the actual time calculated by the SetFreeRunTime function. So when you set a time, you can read it back to find the actual time used by the AE function.

Serial Commands

Target	Index	Command	R/W	Description
05	00	0x0004 = Mode Register #5 Bit# 15: AE Algorithm type	R	If Bit# 15 = 1 then AE algorithm is the newer (time based) version.
04	1d	Auto Exposure	W	0x0000 = Disable AE 0x0001 = Enable Fast AE 0x0002 = Enable Slow AE 0x0003 = Enable small AED counter (1mpix) 0x0004 = Enable large AED counter(16mpix) 0x0005 = Enable AED averaging 0x0006 = Disable AED averaging
04	1e	AE Set point	R/W	The detector value that the AE attempts to reach (including hysteresis). The set-point is dependent on the AED window size and AED maximum value
04	1f	AE Hysteresis	R/W	Added and subtracted from set point to determine a stable area for the AE.
04	20	AE max gain	R/W	Maximum digital gain to use in AE
04	21	AE min gain	R/W	Minimum digital gain to use in AE (should be 0x1000 = 1.0X gain)
04	22	AE max exposure	R/W	maximum exposure time
04	23	AE min exposure	R/W	Minimum exposure time
04	26	AE detector	R	Read by AE algorithm to determine brightness of the image.
04	31	AE detector Average	R	Running average of previous AED's
04	32	AE Vsync Count	R/W	Set to 3 in FRM, 1 in TPE mode
04	33	AE exposure denominator	R/W	Use ~10 for indoor light Use ~200 for outdoor lighting Smaller is faster, too small is unstable
04	34	AE gain denominator	R/W	Use ~2 for indoor light Use ~20 for outdoor lighting
05	00	0x0004 = Mode Register #5 Bit# 1: AE Close IRIS Request		Indicates that the image is too bright for the AE and the IRIS should be closed if possible.
05	00	0x0004 = Mode Register #5 Bit# 0: AE Open IRIS Request		Indicates that the image is to dim for the AE and the IRIS should be opened if possible.

4.7: Exposure: Strobe Signal

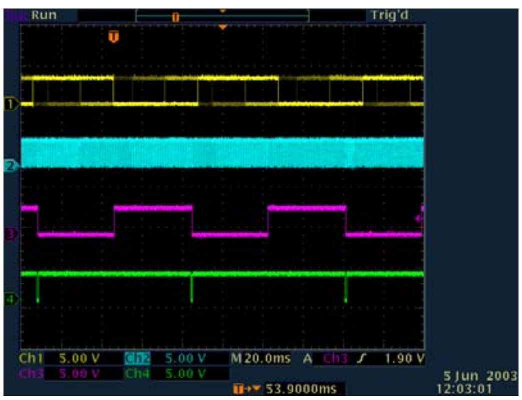
The RMV Strobe signal is a 3.3V LVTTL signal that is active whenever the CCD is exposing and image. The strobe signal is very useful for analyzing and optimizing imaging applications. The strobe can be used to activate an illumination source. The strobe signal should cannot drive significant current and should be buffered if used in this fashion.

Quick FAQ's:

- ►The strobe signal can be used to determine frame timing.
- ►The strobe signal can be found on the RMV power connector and is a 3.3V LVTTL signal.
- ►The exposure detector measures the strobe signal in increments of the pixel clock.

Serial Commands

Target	Index	Command	R/W	Description
04	0e	Strobe Control	Write	0x0000 = negative strobe polarity 0x0001 = positive strobe polarity 0x0002 = Active during free run 0x0003 = Inactive during free run (Always active during trigger)



Free Run Mode (FRM) STROBE:
Yellow = trigger, Blue = LVAL, Red = **STROBE**, Green = FVAL
CCD:4020 Exposure = 0x0400 lines

Trigger Double Exposure (TDE) STROBE:
Yellow = trigger, Blue = LVAL, Red = **STROBE**, Green = FVAL
CCD:4020 TPD = 0x1000

Trigger Programmed Exposure (TPE) STROBE:
Yellow = trigger, Blue = LVAL, Red = **STROBE**, Green = FVAL
CCD:4020 TPD = 0x1000

Free Run Synchronize (FRS) STROBE:
Yellow = trigger, Blue = LVAL, Red = **STROBE**, Green = FVAL
CCD:4020 Exposure = 0x0400 lines

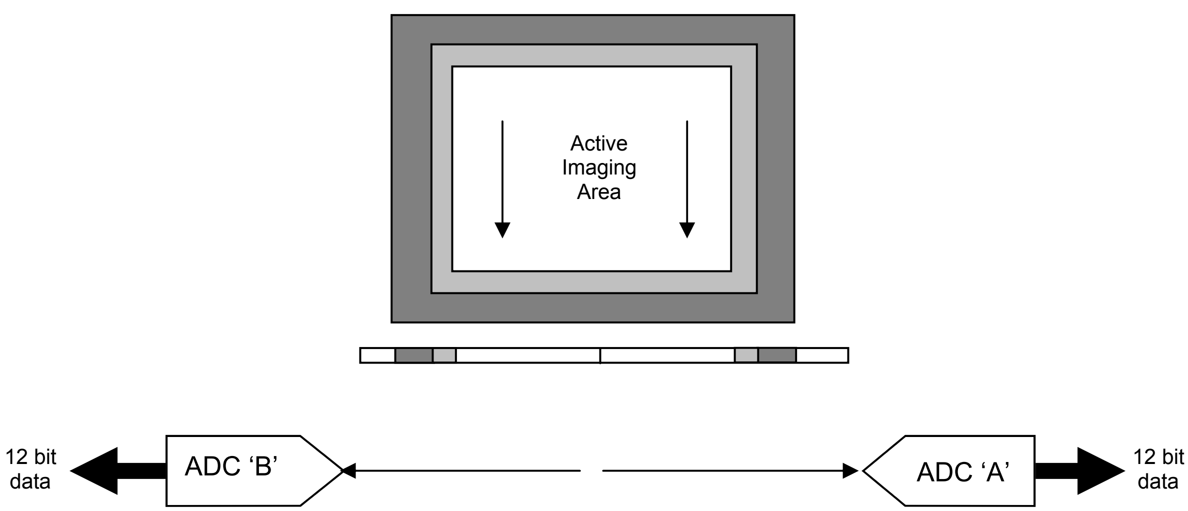
Analog to Digital Conversion

RMV cameras uses two analog to digital converters (ADC) from Analog devices, one for each tap of the CCD sensor. Each ADC has a programmable analog gain stage that can be adjusted from 6dB to 40 dB. Each ADC also incorporates an active black clamp offset control feature. The offset can be selected from 0 to 256 in 12 bit pixel space. The ADC also has a special feature for optimizing color sensor filter response.

Quick FAQ's:
- ►Single tap data is sent through the B tap only.
- ►Dual tap data is sent through both taps, with the B tap on the left side and the A tap on the right side.
- ►Two tap data is reorded in the FPGA TRO circuit.
- ►An ADC maximum gain of 40dB is 100X !
- ►Use the offset to raise the minimum signal above zero to see all system noise.

Serial Commands

Target	Index	Command	R/W	Description
00	01	A: Gain	R/W	A channel controls
00	02	A: Clamp Level	R/W	
01	01	B: Gain	R/W	B channel controls
01	02	B: Clamp Level	R/W	



The RMV uses Truesense Imaging CCD sensors with a two tap output in a left/right format. The sensors can be used with either the single left tap or both taps. **The A tap is the right side and the B tap is the left side when viewed on the capture card. The Single tap mode data is sent through the B tap.**

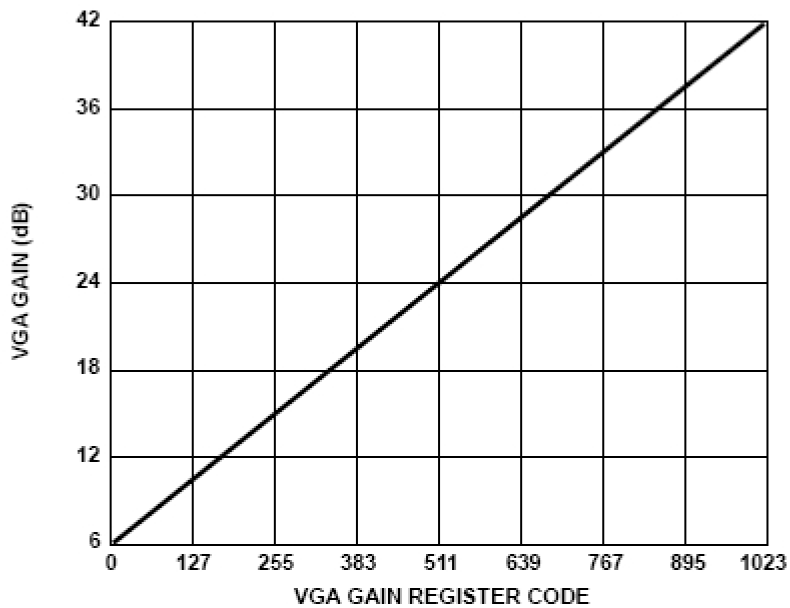
ADC: Gain

The ADC gain range is from 0 to 1023 counts which represents a gain of 2 to 36dB. The pre-gain of the CDS stage adds an additional 4dB of gain resulting in a range of 6 to 40dB. The gain curve follows a linear-in-dB characteristic.

ADC gain can be calculated with the following equation.

Gain (dB) = 5.1 + (0.0359 * code)

Where code is the range of 0 to 1023.



ADC: Offset

The optical black clamp loop removes residual offsets in the signal chain to track low frequency variations in the CCD's black level. During the optical black (shielded) pixel interval on each line, the ADC output is compared with a fixed black level reference, set by the offset value. The offset value can be programmed between 0 LSB and 255 LSB. The resulting error signal is filtered to reduce noise, and the correction value is applied to the ADC input through a D/A converter. The optical black clamp is turned on once per horizontal line.

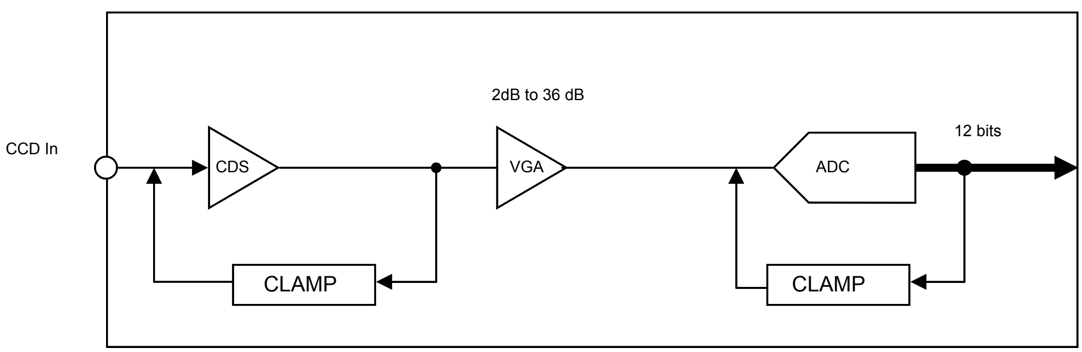
ADC: Black Clamp

The ADC provides an active black clamping circuit that removes the CCD's optical black offset. This offset exists in the CCD's shielded black reference pixels. The ADC removes this offset in the input stage to minimize the effects of gain change on the system black level. During the optical black (shielded) pixel interval on each line, the ADC output is compared with a fixed black level reference selected by the value in the clamp register. The Clamp level is programmed in 8 bit resolution. If external digital clamping is used during the post processing the black clamp can be disabled.

Quick FAQ's:
- ►Each tap has its own ADC and thus its own clamping circuit.
- ►Clamp values for each tap can be adjusted independently.
- ►Clamp is often referred to as black offset.
- ►Use the clamp offset to raise the minimum signal above zero to see all system noise.
- ►**The DGO does not subtact the ADC clamp value before gain and offset are applied !**

Serial Commands

Target	Index	Command	R/W	Description
00	02	A: Clamp Level	R/W	
01	02	B: Clamp Level	R/W	

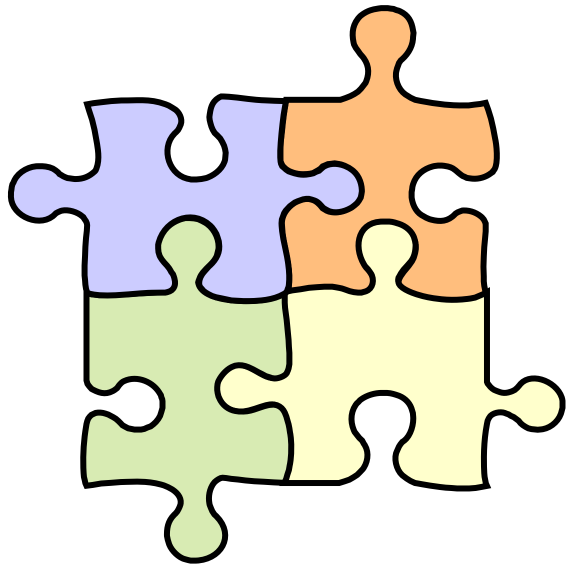


RMV: Sensor, CDS, Analog to digital, and Clamping

illunis

Chapter 5: Image Processing

Rugged Machine Vision



5.0: Image Processing
Overview

The RMV FPGA implements image processing features that are very useful to many imaging applications. These include reordering of the sensor image data, correction of pixel defects and responses, mapping the video data using a programmable look up table, and video analysis tools.

The flow of image data from the CCD Taps to the LVDS output drivers is as follows:

a) Image data is read from the sensor in a raw form. The image data is represented as 12 bits per pixel. The data is processed as 12 bits until the last stages where it is formatted into the selected Camera Link format.

b) Video Tap data is reorder to create a single corrected image

c) Video data is passed through the detectors in the reordered but unmodified format

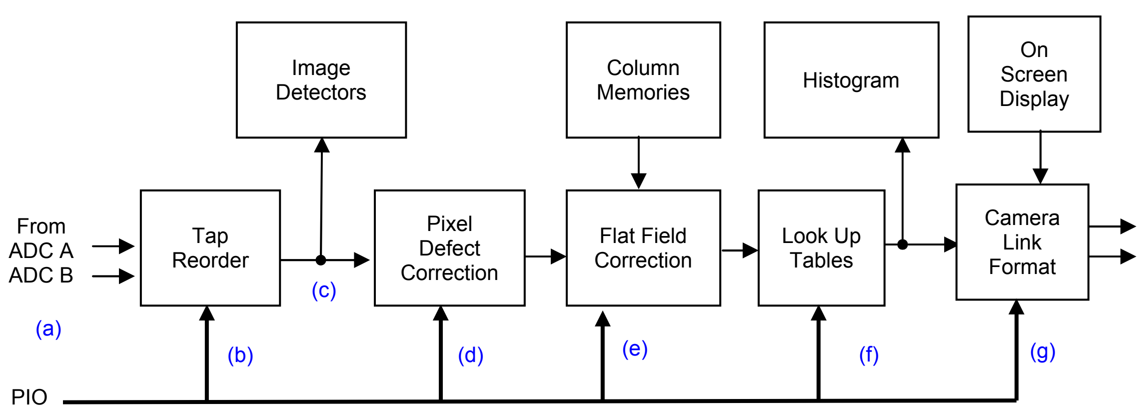
d) The Video data is then optionally corrected for gross defects

d) The Video data is then optionally corrected for column gain.

d) The data is then passed through an optional look up table (LUT) . The LUT converts the 12-bit video data to any 12-bit value.

g) The final processing stage formats the video data for the output LVDS circuitry. This stage permits one or two channel output, bit and tap flipping, 8 and 12 bit/pixel formatting for camera link. This stage also provides the test pattern and on screen display functions

Notes: PIO = parallel IO from microprocessor.



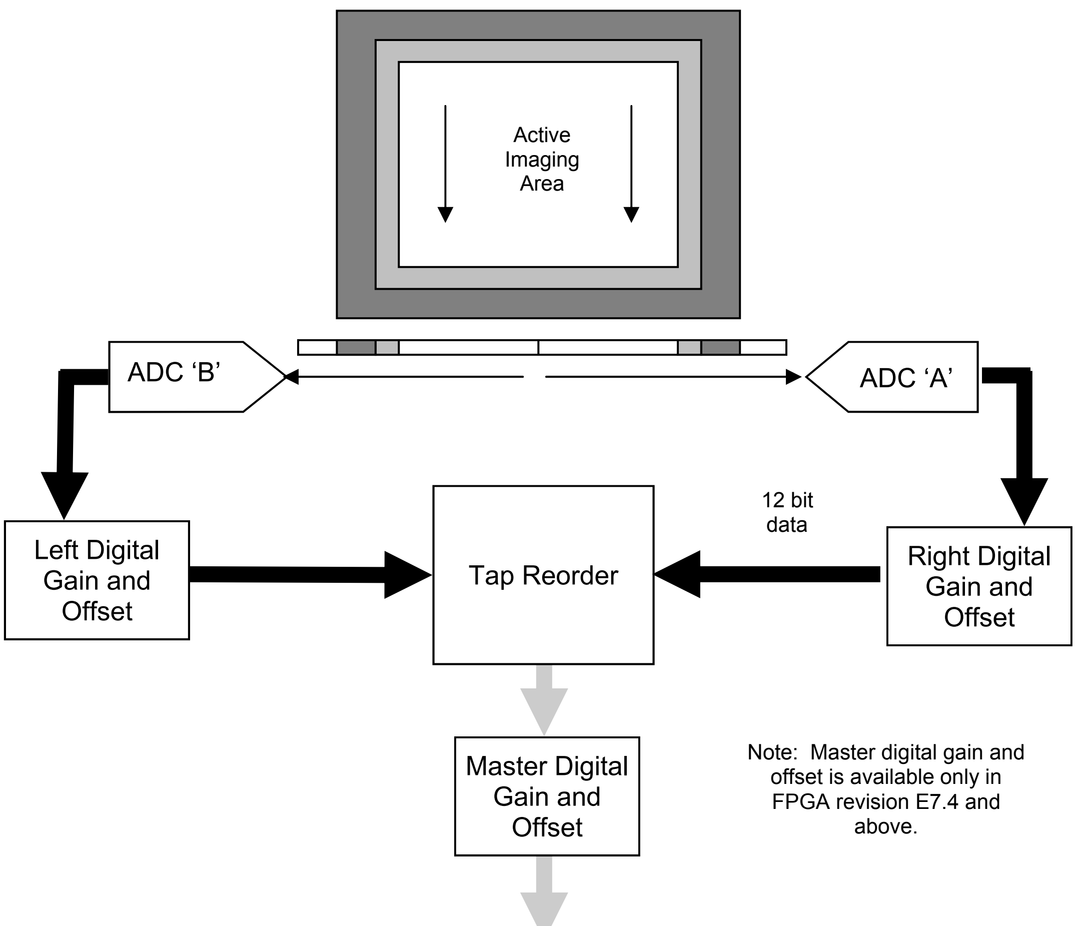
Tap Reorder

Tap Reorder (TRO) is used to combine the two tap video output of the CCD into a single raster.

Quick FAQ's:
► TRO can be used to flip the image horizontally.
► TRO mode is automatic in two tap operation.

Serial Commands

Target	Index	Command	R/W	Description
04	00	Single Tap Enable	W	0x0000 = Dual Tap 0x0001 = Single Tap
04	02	Image Flip	W	0x0000 = Normal 0x0001 = Right/Left Flip
04	1b	System Registers	R	0x0005 = TRO Left Start 0x0006 = TRO Right Start 0x0007 = TRO Size



Tap Reorder and Digital Gain/Offset Circuits

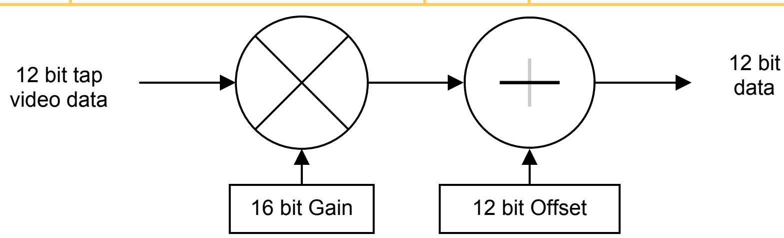
Digital Gain and Offset

Digital Gain and Offset (DGO) are used in situations where analog gain and offset are either to course or not applicable. The digital gain ranges from 0.002 to 16x in 0.002 increments. The digital gain is represented as a hex number where 0x1000 represents a gain of 1X. The digital offset ranges from –4095 to +4095 in increments on 1 count. These gain and offset ranges allow for full 12 bit precision without round-off error. There are separate DGO enables for free run and

Quick FAQ's:
- ▶DGO can be used to match taps when ADC gain and offset are not fine enough.
- ▶DGO is applied to each tap before tap reorder.
- ▶DGO can be set to be active in either free run mode or triggered mode.
- ▶DGO gain is applied first, then the offset is added.
- ▶**The DGO does not suptract the ADC clamp offset before the gain/offset is applied. Thus color processing may be incorrect unless ADC clamp is set to zero.**
- ▶Master DGO affects both taps equally.
- ▶Use Master DGO for gain and offset and individual DGO for extra fine tap balancing.

Serial Commands

Target	Index	Command	R/W	Description
04	04	Mode Register	W	0xM005 = Enable Digital Gain and offset 0xM006 = Disable Digital Gain and offset
M = 0: Common—both, M = 8: Free Run only, M = 4: Trigger only				
04	2c	A Tap Digital gain	R/W	
04	2d	A Tap Digital offset	R/W	
04	2e	B Tap Digital gain	R/W	
04	2f	B Tap Digital offset	R/W	
Master digital gain and offset (MDGO) are available on in FPGA revision E9 and above. MDGO is independent of the Trigger and Free run modes. MDGO is used for histogram equilization.				
04	36	Master Digital Gain	R/W	
04	37	Master Digital Offset	R/W	
04	38	Master DGO Enable	R/W	1 = enable, 0 = disable



Digital Gain and Offset

Digital Gain and Offset

	Minimum setting	Minimum value	Step	Maximum setting	Maximum value	Nominal Value	Nominal Setting
Gain	0x0000	1/4096	1/4096	0xFFFF	16x	1x	0x1000
Offset	0x8FFF	-4095	1	0x0FFF	+4095	+0	0x0000

Pixel and Column Defect Correction

Pixel defect correction (PDC) is used to correct gross defects in an image sensor. The PDC circuit can force pixels to black or white, replace pixels with the left or right neighbor, or an average of their neighbors, or the last pixel corrected. There are separate PDC enables for free run and trigger modes. The PDC circuit can operate on either pixels or columns (not both). The column corrector is useful for DSC grade sensors. The PDC is loaded from a specially formatted file.

Quick FAQ's:

- ▶PDC can be enabled for both triggered and free run modes.
- ▶PDC can operate on either pixels or columns.
- ▶Up to 511 pixels or columns can be corrected
- ▶Using the "force to 1" mode a cursor can be created.
- ▶PDC is applied after the digital gain offset and before Look Up Table
- ▶FPGA Revision E7 adds a second PDC

Serial Commands

Target	Index	Command	R/W	Description
04	04	Mode Register	W	**0xM009** = Enable PDC **0xM00A** = Disable PDC
04	1C	PDM Mode	W	0x0000 = Disable column mode 0x0001 = Enable column mode 0x0002 = Load PDM from EEPROM, leaves PDC on in common mode
M = 0: Common—both, M = 8: Free Run only, M = 4: Trigger only				

Correction Type	Code
No correction	0
Copy from right pixel	1
Copy from left pixel	2
Copy Average : (left+right)/2	3
Force White	4
Force Black	5
XOR pixel	6
Replicate	7
Copy Bayer Average : (2left+2right)/2	8
Copy Bayer right	9
Copy Bayer left	10
Not Defined	11-15

Pixel Defect Correction Values

```
Serial Number 4321
1,1, 4
ffff,ffff,ff
```

Pixel Defect Correction File

Example of white dot at sensor origin

```
Serial Number 4321
400,0,4
410,0,1
420,0,2
430,0,5
440,0,3
450,0,5
460,0,6
470,0,8
480,0,6
490,0,7
500,0,5
510,0,9
520,0,5
530,0,10
540,0,4
ffff,ffff,ff
```

Column Defect Correction File

Example of column

5.4: Image Processing
Look Up Table

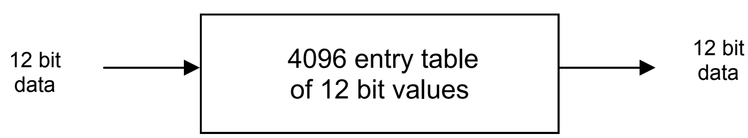
Look Up Tables are used to transform video data from sensor samples to any arbitrary value. Any 12bit value can be transposed into any other 12 bit value. LUT's can be loaded from tables stored within the camera or directly from your application.

Quick FAQ's:

- ►LUT's are 12 bit to 12 bit look up.
- ►The most common use for a LUT is gamma correction.
- ►LUT's can be stored in the camera EEPROM and can be reloaded each time the camera is powered with a single command.
- ►To save a LUT to EEPROM set the LUT mode to 0x0001 and load a LUT from the com port. The LUT will be saved to EEPROM and can be reloaded from EEPROM with the LUT mode 0x0002
- ►When saving a LUT to EEPROM the load time will be longer.
- ►The LUT EEPROM is not initialized for you.

Serial Commands

Target	Index	Command	R/W	Description
04	04	Mode Register	W	0xM007 = Enable LUT 0xM008 = Disable LUT
M = 0: Common—both, M = 8: Free Run only, M = 4: Trigger only				
04	18	LUT load command	W	
04	45	LUT mode	R/W	0x0000 = load from com port 0x0001 = load from com port and save to EEPROM 0x0002 = load from EEPROM
04	46	Gamma LUT	W	Loads a gamma LUT where data is a number from 1-100 = gamma * 100 Note 45 dec = 0x2D hex



Look Up Table Block Diagram

```
0, 0
1, 96
2, 132
3, 159
4, 180
…
4093, 4094
4094, 4094
4095, 4095
```

Example LUT File of 0.45 gamma table
(Some values omitted due to space constraints)

Look Up Table Continued

The Look Up Table (LUT) is loaded using a sequence of character commands that are acknowledged with a return character from the camera. Each command component should wait for the return character and check its status.

The table must be loaded in two passes as the internal FPGA data path to the LUT memory is only a single byte wide. The high byte is loaded in the first pass, then the low nibble is loaded in the second pass.

The command sequence for loading the LUT is as follows:

Command	Ack char	Description
{w04450001FF}	: **!**	Optional save to EEPROM while loading
{w0418000000}	: **!**	LUT load command
>	: **!**	Starts the LUT load sequence
Send 4096 entries for the LUT high byte		
#xxxx	: **@**	Loads a byte to the LUT where xxxx = hex number high byte Example: 0x1234 => 0x12
	: **$**	Indicates end of first sequence
Send 4096 entries for the LUT low byte		
&xxxx	: *****	Loads a byte to the LUT where xxxx = hex number low byte Example: 0x1234 => 0x34
	: **%**	Indicates end of second sequence
Acknowledgement of load sequence		
	: **!**	Indicates end of LUT load

Once the LUT is saved into EEPROM it can be reloaded into the FPGA with:

Command	Ack char	Description
{w04450002FE}	: **!**	Set to EEPROM load mode
{w0418000000}	: **!**	LUT load command from EEPROM

Smear Reduction Circuit

The SRC uses the OSLP circuits to measure the smear signal in the sensor optical (top) black area and subtract this from the image during readout. The VIDEO LINE register is used to select the line to measure (smear). This line should always be in the black area at the top or bottom of the image. The line selected, in which to measure the smear signal, is saved to a memory. As the image is read from the sensor the smear data is subtracted from the image on a column-by-column basis. Since this subtraction removes the analog offset of the image we can use the VIDEO OFFSET to add a fixed offset to the image.

Please contact Dave (dave@illunis.com) for technical information and assistance on how to use the SRC.

The math for the SRC is:

VID_SRC(n) = VIDEO(n) - SMEAR_DATA(n)
+ VIDEO_OFFSET

Quick FAQ's:

- ►All interline transfer CCD's have some smear.
- ►Smear is created when light leaks into the vertical CCD storage area and is most visible at short exposures of images with bright objects.
- ►The VIDEO LINE register is forced to ZERO upon activation of SRC.
- ►Over-clock is different from Over-scan. Over-clock adds 16 lines to the image readout. Over-scan enlarges the readout area to include optical black regions.
- ►Note: Not all Truesense Imaging sensors top optical black regions are light shielded. Use the over-scan readout to view these regions before setting SRC.
- ►For a RMV-11000 use (as a base set)
  Line of interest = 0x000A
  Enable SRC subtraction

Serial Commands

Target	Index	Command	R/W	Description
04	E0	SRC	W	0x0000 = Disable SRC 0x0001 = Enable SRC subtraction 0x0002 = Enable SRC average 0x0004 = Enable 16 line over-clock 0x0005 = Enable fast ASYNC reset flush 0x0006 = Disable fast ASYNC reset flush 0x0007 = Disable 16 line over-clock
05	00	Camera mode registers	R	0x0002 = read mode register 3
04	12	Line Plot Offset	R/W	= VIDEO_OFFSET
04	13	Line Plot Scale	R/W	
04	14	Line Plot Line of Interest	R/W	= VIDEO_LINE
04	11	OSD lines	W	0x0000 disable line plot 0x0001 enable line plot 0x0002 enable column plot 0x0008 draw as line 0x0009 draw as filled
02	0C	Triggered VCCD on	W	VCCD clocks during triggered exposure
02	0D	Triggered VCCD off	W	No VCCD clocks during triggered exposure

Mode Register #3

Bit	Name	Description
15	**SRC Over Clock**	**Adds 16 lines to the sensor readout**
14	**SRC Wave**	**WARNING: Do not use unless you understand this feature !**
13	**SRV Average**	
12	OSD Filled Plot	
11	**SRC Enable**	

Smear Reduction Circuit: Cont.

Special Notes on the use of the Smear Reduction Circuit:

To enable the SRC do the following:

Enable the OSD line plot:	**{w04110008F8}**	
Set the line of interest	**{w0414000AF6}**	(For RMV-11M)
Enable SRC**:**	**{w04E00001FF}**	
Enable SRC Average**:**	**{w04E00002FE}**	(Reduces fixed pattern noise)
Set the SRC offset:	**{w0412000000}**	(User preference)

At this point the SRC will start

Notes:

Interline transfer CCD's have smear that results from light leaking into the vertical CCD. The smear exists in all images, however the smear is most visible in images that have extremely bright highlights and very short exposure times (such as aerial imaging). Smear is created in these modes of operation:

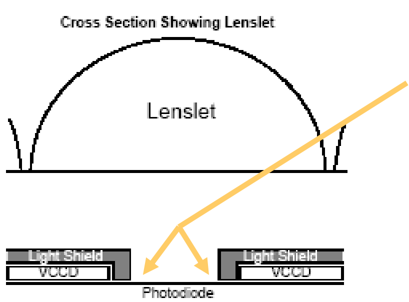
Triggered images; During the pre flush of the VCCD. This smear can be reduced by flushing the VCCD faster and by subtracting the smear information in the top optical black area (as shown in the above SRC example).

Image readout: During the image readout bright highlights will add smear to the image as it is readout. This smear can be detected by over-clocking the sensor and subtracting that data from the image. This must be preformed using post processing software. If the camera is in free run mode this readout smear can be reduced by subtracting the smear data in the top black.

Note that if the bright highlights are moving, during readout of the image, then the smear data may not allow for significant correction.

It is recommended that if you need to use the SRC that you capture images with both the over-scan (of the optical black) and the over-clock (additional 16 lines of image data) modes. The additional image data can be used for post processing of the image for smear reduction.

Note: Not all sensors top optical black regions are light shielded. You can use the over-scan readout and OSLP to view these regions before setting SRC.



Smear is caused by light leaking into the VCCD.
Very bright images and short exposures exaggerate the smear.

Flat Field Correction

Flat Field Correction is best handled by your capture card or software. Contact our office for more information.

Automatic Tap Matcher

The two tap sensors require two sets of analog to digital converters and associated circuitry. Along with variances in the sensor manufacturing these two paths are rarely exactly the same. In addition the effects of temperature, optics and gain can cause the tap imbalance to be visible.

Thus we need to balance the two taps through the use of analog gain. The Automatic Tap Matcher (ATM) uses the tap crack detectors to determine the tap mismatch and then applies analog gain to attempt to correct the imbalance.

The tap matcher runs at full speed of the crack detectors (every 64 frames).

Applications that will benefit from the ATM are Arial imaging, portrait photography, and microscopy. Applications that should not use ATM are PCB and LCD inspection, imaging with regular features and fixed patterns and PIV particle fields.

Quick FAQ's:

►The ATM is designed to work with randomly changing images that present unstructured image data to the crack detectors.

►The crack detectors must be set to color mode if the sensor is a Bayer pattern color device. It is a good idea to use the color mode all the time with the ATM.

►The ATM on/off state is saved with the camera state.

►The ATM will change the analog gains by no more than one count (up or down) on any given correction.

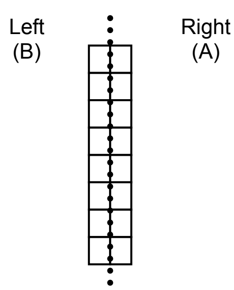
►The ATM correction is scene dependent. If the image data presented to the tap crack detectors is unbalanced then the ATM correction will cause the taps to become unbalanced.

►The ATM correction is performed by adjusting the right analog gain.

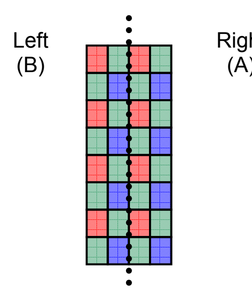
►NOTE: If the state of the camera is saved, the ATM modified analog gains will also be saved.

Serial Commands

Target	Index	Command	R/W	Description
09	00	Tap Match On/Off	R/W	0 = off. 1 = on
05	00	Camera mode	R	0x0000 = read mode register 1
04	11	OSD modes	Write	**0x000a enable color mode** 0x000b disable color mode



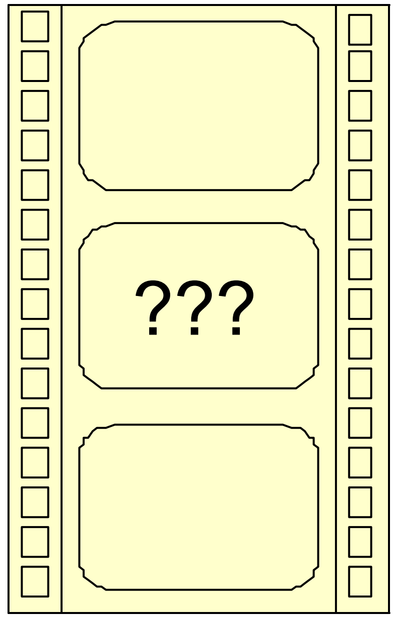
Mono Mode Crack Detector



Color Mode Crack Detector

Chapter 6: Detectors

Rugged Machine Vision

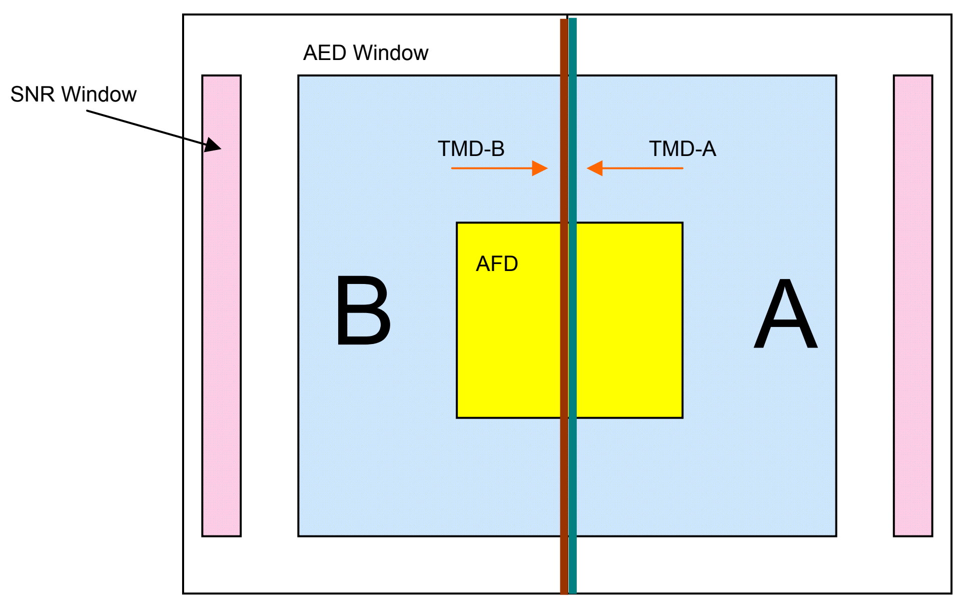


Overview

The RMV incorporates several video "detectors" that analyze imagery in real time. The video detectors measure exposure, focus, SNR and tap-to-tap balance. The exposure detectors operate in several modes that allow the measurement of both image brightness and tap-to-tap matching. The focus detectors measure the sharpness of the image and can be used for auto focus optics. In addition to the detectors the windows of the detectors can be overlaid on the video image.

Detector Windows

Each detector has its own window that it uses for analyzing the video data. The Auto Exposure (AED) and Auto Focus (AFD) detectors and Signal to Noise Ratio (SNR) are updated on every image read from the sensor. The Tap Match (TMD) detectors sample 256 images. The detector windows are:



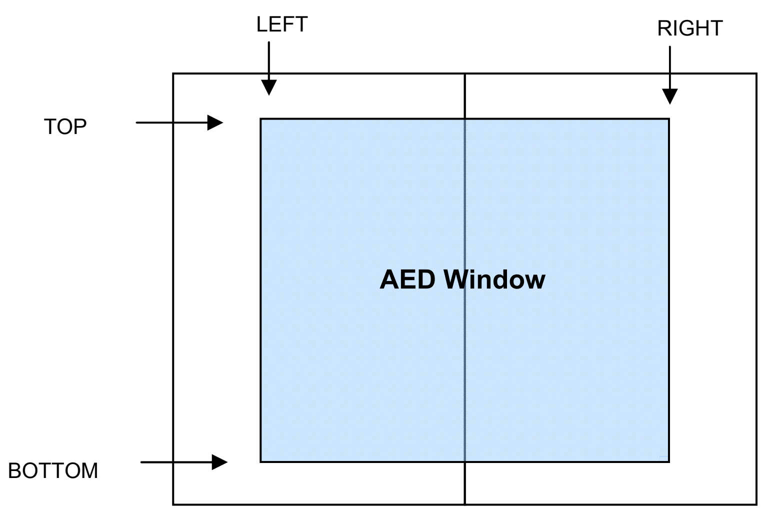
Brightness Detector

Brightness detector measure the brightness of the image within the auto exposure detector (AED) window. The AED sums the values of the image data within the window. The top 15 bits of the summed data is output as the AED data. The MSb of the AED is a negative logic flag indicating that the data is valid. Thus if the highest bit (0x8000) of the AED is set then the AED value is INVALID. To change the AED position you must use the PIO twin command write, this requires writing the data first and then the address for the data second.

Quick FAQ's:
- ►Brightness is also called AED
- ►The AED window size is programmable.
- ►The small AED was designed to use a window size of 1M pixel, thus a window of 1k x 1k pixels is standard.
- ►The large AED window can measure up to 16Mpix,
- ►If the high bit of the AED is set then the data is not vaild. Data can become invalid during a ASYNC RESET mode and a triggered image .
- ►The AED window can be displayed as an overlay.

Serial Commands

Target	Index	Command	R/W	Description
04	1d	Auto Exposure Detector (Counter)	W	0x0003 = Enable small AED window 0x0004 = Enable large AED window
04	19	Show Detectors	W	0x0002 = AE Window 0x0009 = disable
04	1a	Read Detectors	R	0x0002 = AE Window
03 03	0c 13	AE Detector Data Top Register Address	R/W	Location in units of 16 lines 0x003d = Set AE Top location
03 03	0c 13	AE Detector data Right Register Address	R/W	Location in units of 16 pixels 0x003e = Set AE Right location
03 03	0c 13	AE Detector data Left Register Address	R/W	Location in units of 16 pixels 0x003c = Set AE Left location
03 03	0c 13	AE Detector data Bottom Register Address	R/W	Location in units of 16 lines 0x003F = Set AE Bottom location



Sharpness Detector

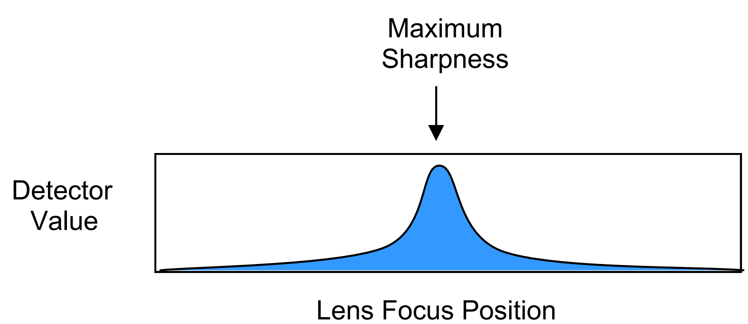
Sharpness detector uses a fixed window centered on the image area and 512 x 512 pixels in size. The sharpness detector can be used as a auto focus detector (AFD). The AFD calculates sharpness as the summation of the difference of the pixels within the window.. The top 15 bits of the summed data is output as the AFD data. The MSb of the AFD is a negative logic flag indicating that the data is valid. Thus if the highest bit (0x8000) of the AFD is set then the AFD value is INVALID.

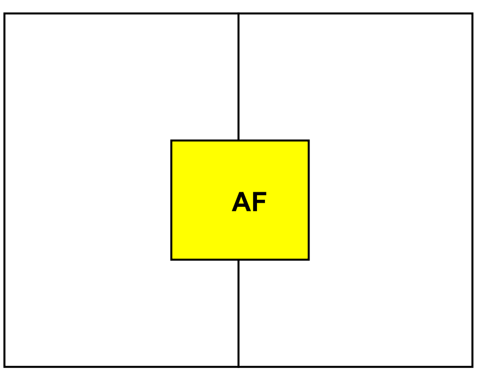
Quick FAQ's:

- The AFD window size is fixed in the center of the image.
- If the high bit of the AFD is set then the data is not vaild. Data can become invalid during a ASYNC RESET mode.
- The AFD window can be displayed as an overlay.
- The AFD data can be displayed as video data showing either the first or second derivative.
- The AF value peaks sharply when the image is at it's maximum sharpness.

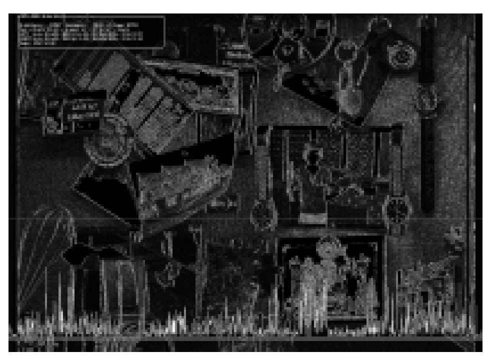
Serial Commands

Target	Index	Command	R/W	Description
04	19	Show Detectors	W	0x0003 = AF Window 0x0007 = AF Data in AF Window 0x0008 = AF Data Full Screen 0x0009 = disable
04	1a	Read Detectors	R	0x0003 = AF Window





AFD Detector Window Location



AFD Detector Derivative Image
(whole screen)

Tap Matching Detectors

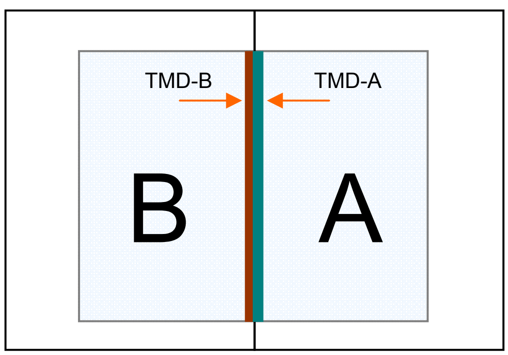
Tap Matching Detectors (TMD) are used to determine how close the taps match in two tap systems. The TMD are single (or double in the case of color mode) column wide windows that are located at the sensor tap boundary. The TMD sum all of the pixels in the window are over 64 frames. The TMD works best with images that are not static. The TMD data does not become valid until the 65th frame readout. The user must implement a matching algorithm using these detector values. It is recommended that the Digital Gain be used for this.

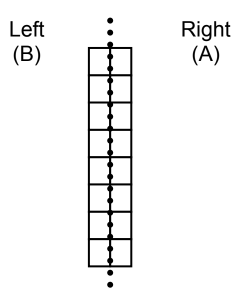
Quick FAQ's:

- ►The TMD's are used to determine the relative brightness of the two sensor taps.
- ►The TMD's can be displayed as an overlay.
- ►The color mode makes the TMD two pixels wide so that the four colors of the Bayer pattern are sampled.
- ►The TMD's vertical limits are set by the AED window.

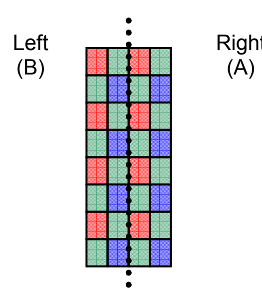
Serial Commands

Target	Index	Command	R/W	Description
04	19	Show Detectors	W	0x0000 = Tap A Crack 0x0001 = Tap B Crack 0x0009 = disable
04	1a	Read Detectors	R	0x0000 = Tap A Crack 0x0001 = Tap B Crack
04	11	OSD modes	W	0x000a enable color mode 0x000b disable color mode





Mono Crack Detector



Color Crack Detector

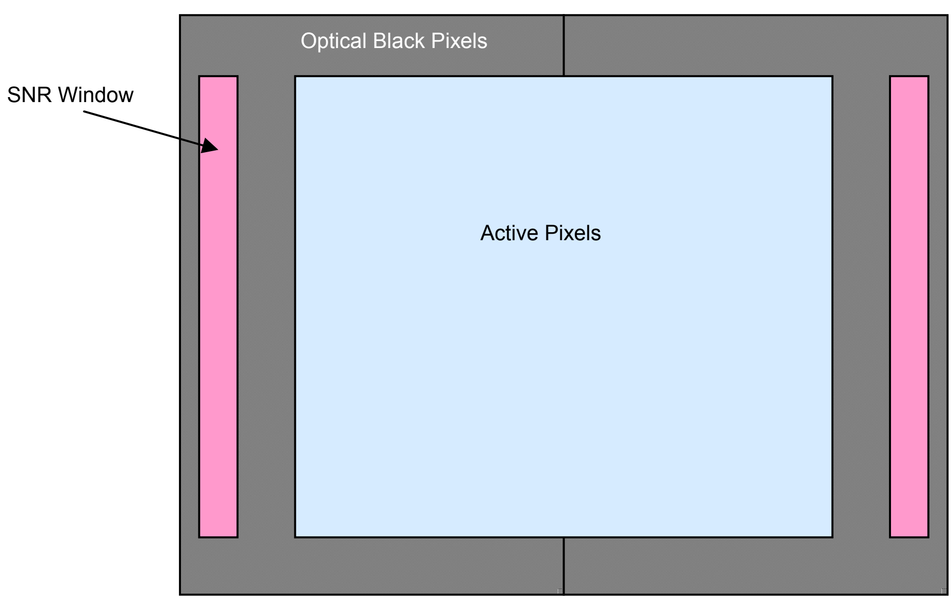
SNR: Signal and Noise Detectors

The SNR detectors are used to measure system noise and signal amplitude. From these measurements a signal to noise ratio can be calculated. See the following section for the mathematics required to calculate SNR. By dividing the SNR sum values be the number of samples, the accuracy of the black clamping can be measured. There are separate detectors for the left and the right taps.

Quick FAQ's:
- SNR detectors are very useful for measuring camera performance.
- SNR can be measured live and displayed as on screen text.
- The SNR window position is programmable. Thus the active imaging area can be used to measure noise. Call or email info@illunis.com for details.
- The SNR window vertical limits are set by the AED window.

Serial Commands

Target	Index	Command	R/W	Description
04	19	Show Detectors	W	0x0004 = SNR Left 0x0005 = SNR Right 0x0009 = disable
04	1a	Read Detectors	R	0x0004 = Left SNR Sum 0x0005 = Left SNR Sum of Squares 0x0006 = Left SNR Number of Samples 0x0007 = Right SNR Sum 0x0008 = Right SNR Sum of Squares 0x0009 = Right SNR Number of Samples 0x000a = Left SNR Max Value 0x000b = Right SNR Max Value



The RMV can calculate SNR on each frame by analyzing the noise in the black clamp areas of the CCD and measuring the maximum pixel brightness in the image area. The detector measures:

N	Number of pixels in SNR detector window
SUM	Sum of the pixel values in the SNR window
SQR	Sum of the square of the pixel values in the SNR window
MAX	Maximum pixel value of the tap area intersected by AE window area

From these numbers we calculate

Bmean = SUM / N;
Bsdev = √ ((N * SQR - SUM * SUM) / (N * (N -1)));

Bmean must be greater than Bsdev * 3
If it is not then the black clamp must be raised

SNR = 20 * log ((MAX - Bmean) / Bsdev)
DNR = ((MAX - Bmean) / Bsdev;
BITS = log (DNR) / log (2); where BITS < 4095
RMS noise in ADC counts = Bsdev—1.0

C Code to calculate SNR from detector values

```
// C Code to Calculate SNR in DB

      fsum        = (float) snr_sum * 16;       // 16 is sum scale
      fsqr        = (float) snr_sqr * 16 * 64;  // 64 is mult scale,
      fn          = (float) snr_n;
      fmax        = (float) snr_max;
      fblk_mean   = fsum/fn;
      fstd_dev    = sqrt( (fn * fsqr - fsum * fsum) / (fn * (fn -1)));

      if( fblk_mean > (3 * fstd_dev) ) // Make sure noise is measurable
            {
            fdr = (fmax - fblk_mean) / fstd_dev;
            fsnr = 20.0 * log10( fdr );
            bits =  log( fdr ) / log( 2 ); // ENOB
            }
```

System Noise Calculation:

The noise can be calculated as fstd_dev from above in counts.
at 244.14uV/count we can get the uV of noise

For example the KAI-11002 color camera has a RMS count of 2.3, and 13uV/e

A count of 2.3 => 244.14*2.3 = 561uV of noise
Then 561uV/13uV/e = 43e

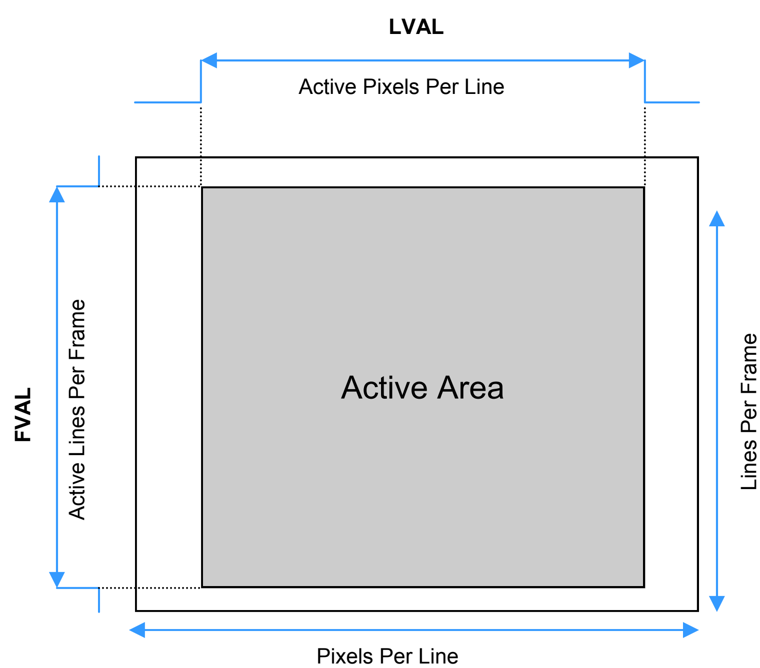
Raster Detectors

Raster detectors (RD) are used to measure the size of the video image output by the RMV camera link signals. The RD's count the number of pixels per line and the number of active pixels per line. The RD's also count the number of lines per frame and the number of active lines per frame. Because the RMV can be set to any number of modes the RD circuit is vital to correctly configuring your capture device.

Quick FAQ's:
- ►LVAL = Line VALid: This Camera Link signal indicates when pixel data is valid with a line.
- ►FVAL = Frame VALid: This Camera Link signal indicates when line data is valid with a Frame.
- ►LVAL start and stop define a lines active pixels and are in some weird internal FPGA counting unit.
- ►FVAL start and stop define a frames active lines and are directly related to the sensor design.
- ►**The Raster line detectors use the "line of Interest" line from the On Screen line plot function to determine which line is measured. The line of interest must be in the visible image data or these detectors will read zero !**

Serial Commands

Target	Index	Command	R/W	Description
04	1b	System Registers	R	0x0000 = Read Pixels/line 0x0001 = Read Active pixels/line (in LVAL) 0x0002 = Read Lines per frame 0x0003 = Read Active lines per frame (in FVAL)
04	14	Line of Interest	R/W	Line number from top of image (Plus FVAL start)



6.6: Image Detectors
Temperature Detector

Temperature of the RMV camera is obtained though a solid state device located on the CCD PCB. The temperature sensor is located as close as possible to the warmest component in the camera. The temperature sensor doe not read the CCD temperature.

Quick FAQ's:
- ►Temperature is read in degrees Celsius.
- ►Temperature accuracy is 0.5 degrees.

Serial Commands

Target	Index	Command	R/W	Description
04	07	Camera Temperature	R	Temperature in degrees Celsius

Example

Read 0x003D = 61(decimal) degrees Celsius

6.7: Image Detectors
Frame Counter

A Frame Counter is implemented in the RMV FPGA. Each frame read has a unique count. You can read the frame count immediately after the rising edge of FVAL. The frame counter is displayed in the On Screen

Quick FAQ's:
- ►The frame counter is a 16 bit counter that rolls over to zero when the maximum count of 65535 is reached.

Serial Commands

Target	Index	Command	R/W	Description
04	1A	Read Detector	R	0x000A = Frame Counter
04	1A	Reset Frame Counter to Zero	W	0x000A = Reset to Zero

6.8: Image Detectors
Built In Test

Built In Test (BIT) is a key feature of the RMV cameras that indicate hardware, software and communication faults. Use the status registers to determine the BIT status.

Quick FAQ's:
- ►IBIT = Initiated BIT

Serial Commands

Target	Index	Command	R/W	Description
04	0c	Micro IBIT	W	0x0000 = Clear Bit Status Register 0x0001 = PBIT

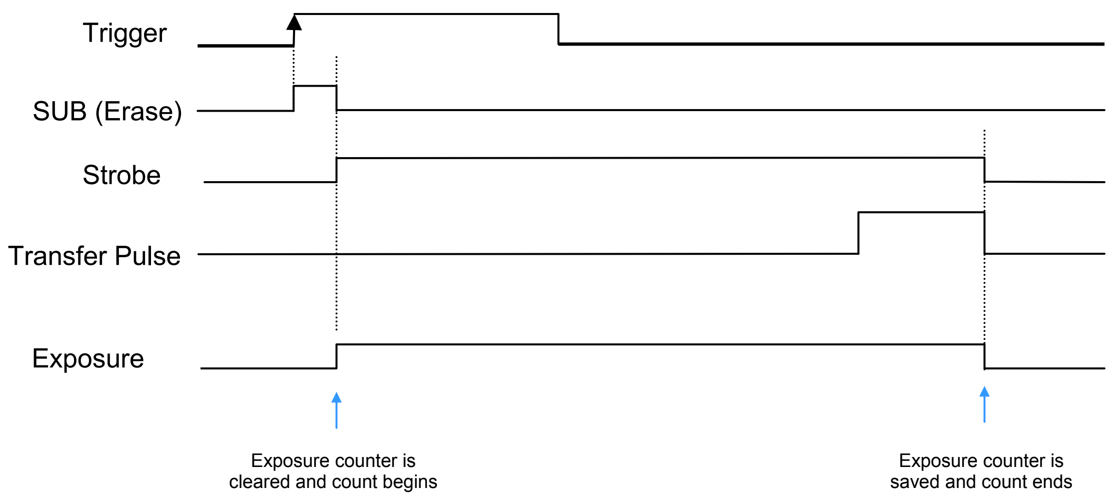
Exposure Time Detector

Exposure Time of the RMV camera is measured with a very high resolution counter circuit. The counter contents are cleared on the electronic erasure pulse and saved on the photo diode transfer pulse. The count resolution is the pixel clock so a very accurate measurement of the exposure can be made.

Quick FAQ's:
- ►Exposure is measure in pixel clock periods
  For a 40Mhz clock the period is 0.025us
  For a 30Mhz clock the period is 0.033us
- ►The maximum count is 4294967295 (0xFFFFFFFF)
  For a 40Mhz clock the maximum is 107 seconds
  For a 30Mhz clock the maximum is 143 seconds

Serial Commands

Target	Index	Command	R/W	Description
04	0x27	Camera Exposure	R	0x12 = Low Word (2 bytes) 0x13 = High Word (2 bytes)



6.10: Image Detectors
White Balance / GNU

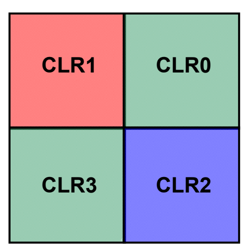
The RMV can be configured as a color camera by utilizing a Bayer patterned sensor. For optimum processing of the Bayer pattern the gains of the two green pixels within each pattern must be matched for uniformity. The RMV incorporates a special circuit that measures a 32x32 pixel area (consisting of 16x16 Bayer quads) for brightness of each of the Bayer colors. Each of the Bayer colors is integrated over the 32x32 pixel area and are read from the CL detector circuit. The detector can be selected for the left side tap or the right side tap. Wait 2 VSYNCS after changing this bit before reading the GNU/WB data.

Quick FAQ's:

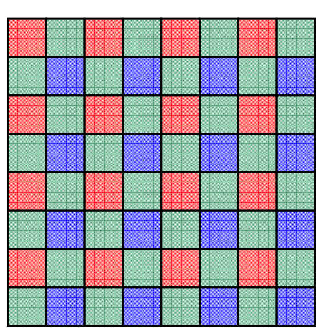
- ►To use the detectors for white balance place the detector location on a calibrated gray color patch and adjust the RGB values to be the same.
- ►To use the detectors for GNU place the detector location on a uniform green patch and balance the Green values to be the same.
- ►The detector window can be seen by activating the AE detector window. The WB/GNU is the small window in the center.
- ►Wait 2 vsyncs after selecting or changing the WB/GNU detector settings before reading the detector .
- ►The WB/GNU detector is read as 16 bit value while the OSD is 8 bit.
- ►Note: Some sensors can have colors in another order from the diagram below.

Serial Commands

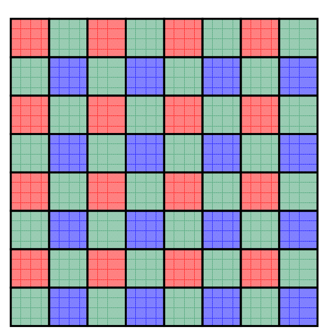
Target	Index	Command	R/W	Description
04	1b	Read WB/GNU detector	R	0x0019 = clr0 (GREEN-RED) 0x001a = clr1 (RED) 0x001b = clr2 (BLUE) 0x001c = clr3 (GREEN-BLUE)
04	35	WB/GNU tap select	R/W	0x0000 = left tap (Power on default) 0x0001 = right tap



The four colors of the Bayer pattern



Left Side GNU/WB Detector



Right Side GNU/WB Detector

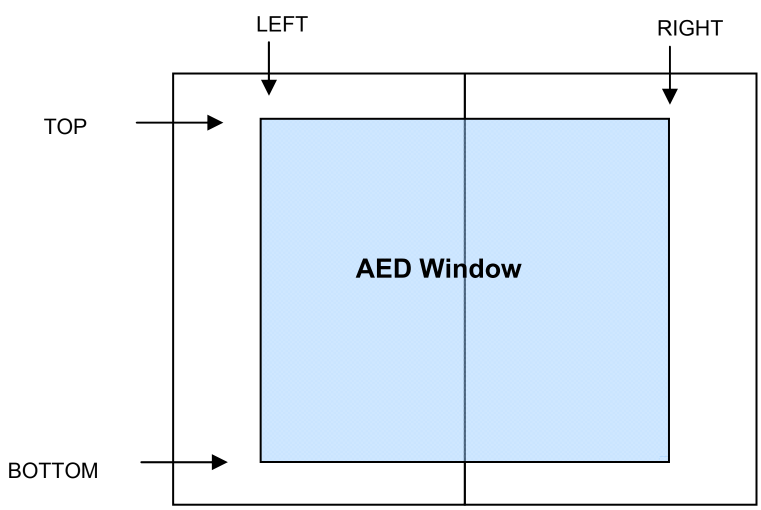
Saturated Pixel Counter

The Brightness detector is used to measure the brightness of the image within the auto exposure detector (AED) window. The Saturated Pixel Counter (SPC) is used to count the number of saturated pixels within the AED window. The SPC has a maximum value of 16 million pixels. The SPC represents the top 16bits of a 24 bit counter that counts pixels whose upper seven bits (of a twelve bit sample) are all ones.

Quick FAQ's:
- ►The Saturated Pixel Counter (SPC) uses the AE window as the ROI for measurement.
- ►The AED window size is programmable.
- ►The SPC register value must be multiplied by 256 to calculate the total number od saturated pixels.
- ►The SPC is useful for determining the set point in the AE alogrithm.

Serial Commands

Target	Index	Command	R/W	Description
04	1a	Read Detectors	R	0x000D = # Sat Pixels
04	1a	Read Detectors	R	0x001D = # Sat Pixels (older version)
03 03	0c 13	AE Detector Data Top Register Address	R/W	Location in units of 16 lines 0x003d = Set AE Top location
03 03	0c 13	AE Detector data Right Register Address	R/W	Location in units of 16 pixels 0x003e = Set AE Right location
03 03	0c 13	AE Detector data Left Register Address	R/W	Location in units of 16 pixels 0x003c = Set AE Left location
03 03	0c 13	AE Detector data Bottom Register Address	R/W	Location in units of 16 lines 0x003F = Set AE Bottom location



Exposure Histogram Detector

The Brightness detector is used to measure the brightness of the image within the auto exposure detector (AED) window.

The Exposure Histogram Detector is used to measure the number of pixels at specific brightness levels through the concept of bins. Bins are used to count the number of pixels within two ADC values that occur in the AED window. The bin sizes are determined by three register values that define points in the ADC count. There are five bins. The typical usage of the bins are: BIN0 is used for black measurement, BIN1 and BIN2 are used to measure mid range, BIN3 is used to measure bright points and BIN4 is used to measure saturated pixels.

In addition to the histogram bin counts a reference count of the number of pixels in the AED window is provided. This reference count can be used easily to calculate percentages of pixel counts within the bins.

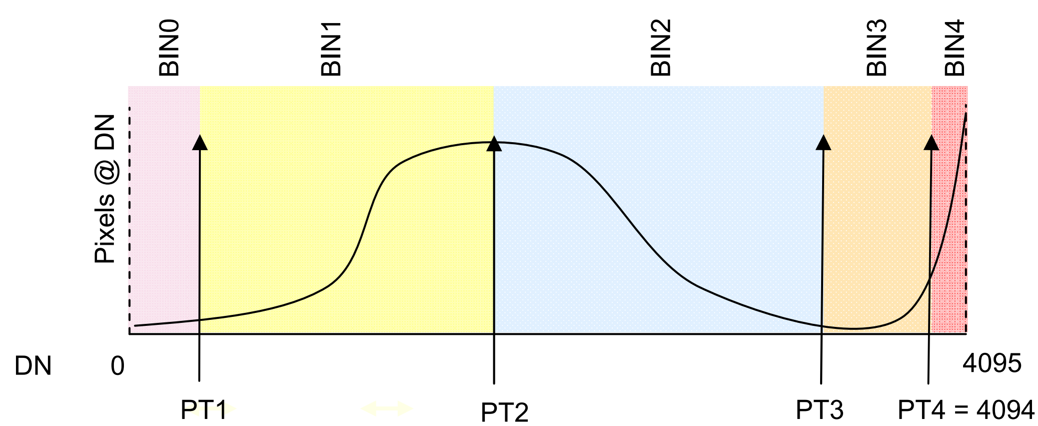
Quick FAQ's:
- ▶The Saturated Pixel Counter (SPC) uses bin 4.
- ▶The bin register values are in units of 16 DN.
- ▶The PT1 value is usually 4X the black clamp
- ▶The PT2 value is usually one half the max count
- ▶The PT3 value is usually 85% the max count
- ▶Typical register values for the points are
  PT1: 0x08 = 0x08 * 16dec = 128 dec DN
  PT2: 0x80 = 0x80 * 16dec = 2048dec DN
  PT3: 0xE0 = 0xE0 * 16dec = 3568 dec DN
- ▶The Auto exposure OSD displays the bin counts and a new super cool bar graph display !

Serial Commands

Target	Index	Command	R/W	Description

04	1a	Read Bin and AED size values	R	0x0011 = Bin #0
				0x0012 = Bin #1
				0x0013 = Bin #2
				0x0014 = Bin #3
				0x0015 = Bin #4 = # sat pixels
				0x0016 = Number of pixels in

03 03	0c 13	AE Histogram Point Register Address	R/W	Location in histogram bin point in units of 16 DN 0x004A = Set AEH point #1 0x004B = Set AEH point #2 0x004C = Set AEH point #3
04	19	Show Detectors	W	0x000A = Blooming 0x0009 = disable



Blooming Detector

The Blooming detector is used to measure the number of pixels in an window that are oversaturated. When used in the bottom black and over clock lines this detector can be used to detect images that have severe blooming.

An image with severe blooming will incorporate an streak of saturated pixels that extends into optical black at the bottom of the sensor and, if enabled, into the over clocked lines.

The Blooming detector uses a window defined by a start line, a size, and the horizontal limits of the Auto Exposure Window. A blooming counter is reset every image.

The pixels within this blooming detector window are compared to the BIN3 and BIN4 values of the auto exposure histogram settings. If the pixels are within these bin's then the blooming count is incremented.

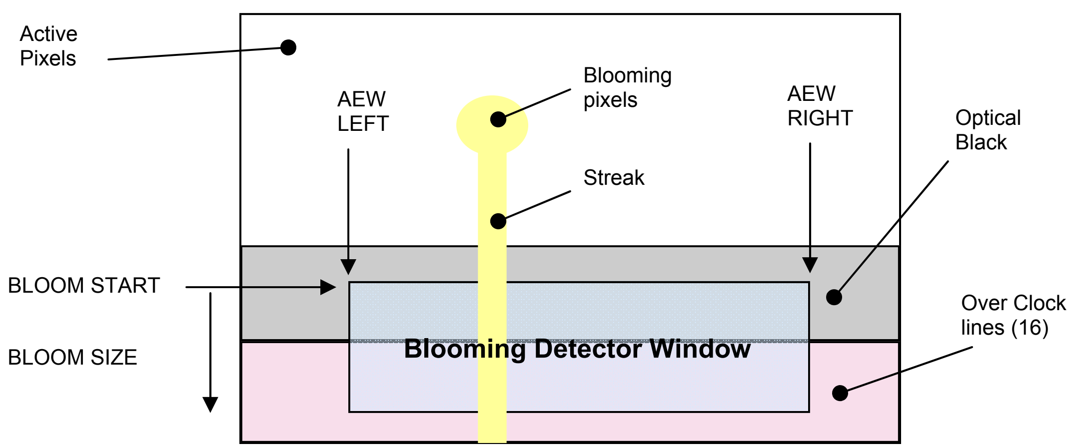
If the blooming count is not zero at the end of a image readout, then there is an excellent possibility that the image has a blooming artifact.

Quick FAQ's:

- The Blooming detector is very useful in aerial imaging applications where an image that is bloomed may be retaken with an alternate exposure.
- The maximum size of the blooming detector is 4096 pixels by 16 lines = 65535 pixels.
- For the RMV-11000 set the over-clock on, then set the start line to 0x0A91 and the size to 0x000F.
- Yes we have detector madness !
- For more information on this feature contact dave@illunis.com

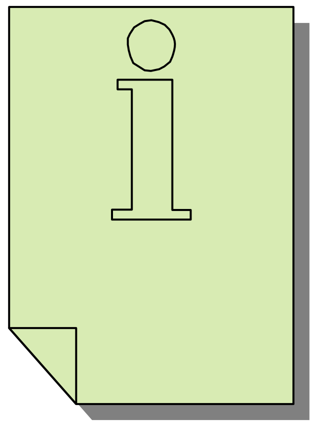
Serial Commands

Target	Index	Command	R/W	Description
04	1a	Read blooming detector	R	0x0017 = Number of pixels blooming
04	50	Blooming detector start line	R/W	Range: 0-4095
04	51	Blooming detector size	R/W	Range: 0-15
04	E0	Over clock lines	W	0x0004 = Enable 16 line over-clock 0x0007 = Disable 16 line over-clock
04	19	Show Detectors	W	0x0002 = AE Window 0x0009 = disable



Chapter 7: OSDisplays

Rugged Machine Vision



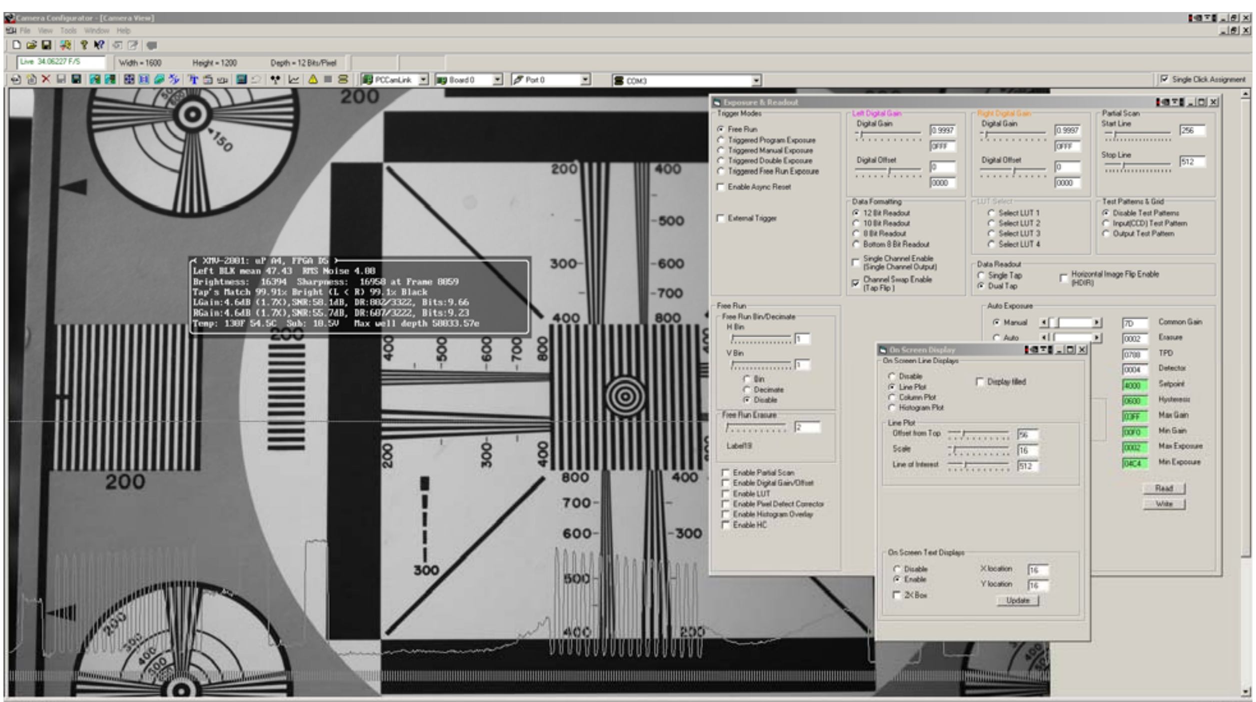
Overview

The Rugged nature of the RMV name comes in part from the cameras ability to display performance and image data as on screen overlays.   The RMV FPGA contains circuits that can do the following:

Display On Screen Text with:
- Programmable character font.
- 128x32 character screen memory.
- Screen memory can be positioned anywhere on image.
- Text can be normal or double size.
- Text can have transparent or opaque backgrounds.

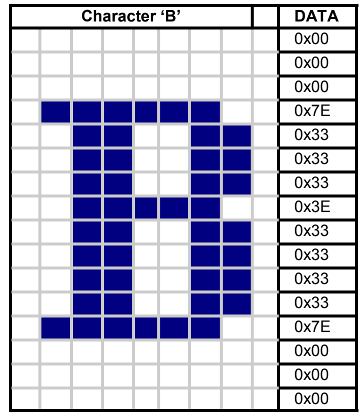
Display a plot of video data with:
- Horizontal (line plot) or Vertical (column plot) display.
- Selectable line/column of interest for display.
- Selectable baseline position for the plot data.
- Scalable plot size from 1 pixel to full scale (4095).
- Plot can be drawn as a single line or as a bar plot.
- All data can be plotted, including the over scan areas.

In addition to the on screen displays the RMV has several image detectors that are used to calculate performance data in real time.   The data is analyzed and displayed using the On Screen Text feature. The following screen image shows some of the on screen functions in operation.



On Screen Text Display

The OSD function can be used to overlay text data on the live video image. Two memories are used to store the OSTD data, one block RAM for the character shape and one Block RAM for the screen memory. The character memory stores the “pixels” used to create the character shape. Character shape data is stored from top to bottom as consecutive bytes, one per line, for a total of 16 lines. Thus the characters are 8 pixels by 16 lines in size. There are a total of 128 characters that are mapped to an ASCII Table. Character shape data is stored in the Microprocessor and loaded into the FPGA at initialization.



The Screen memory is used to store the “character” that is to be displayed as 7 bits of data as well as a single bit used to set the characters background transparency. The screen memory is an array of 128 columns by 32 rows. Each entry in the screen memory is a byte of data that indicates the character index and transparency. The transparency bit sets the background image to 50% intensity if set. The character index is coded as a standard ASCII table so that text can be easily used. The character code is:

Transparency	Character “Address” = ASCII Code						
Bit 7	6	5	4	3	2	1	0

The screen memory is accessed through the OSD address register. The OSD register contains a bit which indicates which memory is to be accessed and the address of the character or screen memory location. To access one of the 128 character memories, as 16 lines of data per character, the OSD address is formatted as a 16-bit word:

Mem Select	Address														
Char Mem	Not used				Character Address							Character Line			
Bit 15 = ‘1’	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0

To access one of the screen memory locations, 128 columns and 32 lines, the OSD address is formatted, with the upper byte as row address and the lower byte as column address, as a 16-bit word:

Mem Select	Address														
Screen Mem	NA		Character Row						Character Column						
Bit 15 = ‘0’	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0

Since the OSD text is limited to a 128x32 array of 8x16 bit characters the bitmap of 1024x512 pixels is smaller than the CCD image area. The OSD Start Register specifies the starting location. The register format is:

Vertical offset in 16 line increments								Horizontal offset in 16 pixel increments							
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0

Quick FAQ’s:

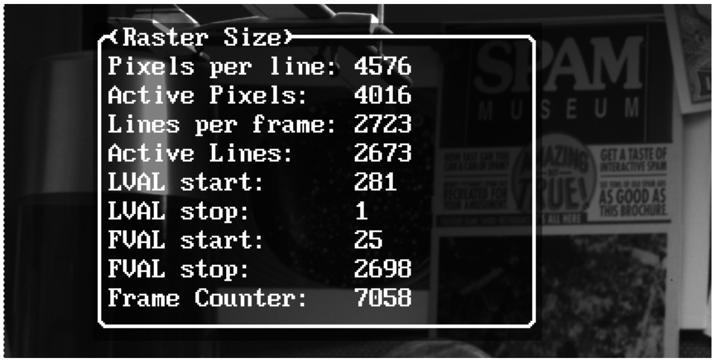
- ►The OSD font is programmable.
- ►The OSD text is displayed as 8x16 pixel font of 128 characters.
- ►The OSD text is displayed on a area 128 characters by 32 lines, The display area can be positioned in the image.
- ►Contact illunis for more information on how to customize the OSD functions.
- ►**Note: Some OSD functions make extensive use of floating point calculations. The micro processor may abort these calculations if an incoming command packet is detected. The OSD display may be temporally invalid if this happens.**

Serial Commands

Target	Index	Command	R/W	Description
04	15	OSD Text	W	0x0000 disable text overlay (All) 0x0001 enable OSD (Detectors) 0x0002 update display window 0x0003 enable 2X window 0x0004 disable 2X window 0x0005 enable OSD (Raster) 0x0006 enable OSD (Revision) 0x0007 enable OSD (Frame Counter) 0x0008 enable OSD (WB/GNU) 0x0009 enable OSD (AE)
04	16	ODS Text Window X location	R/W	Increments of 16 pixels
04	17	OSD Text Window Y location	R/W	Increments of 16 lines

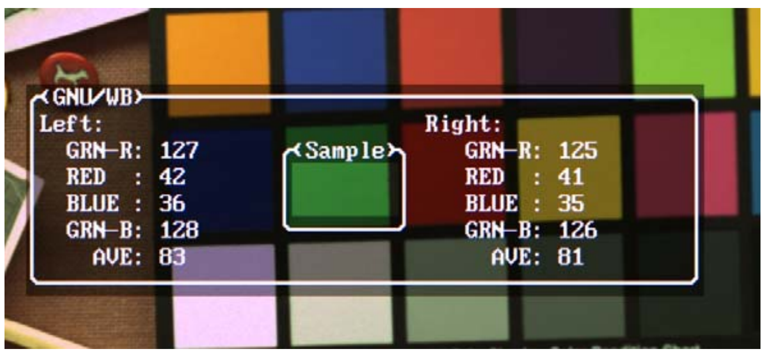
On Screen Text Display: Sensor Performance Information

On Screen Text Display: Camera Information

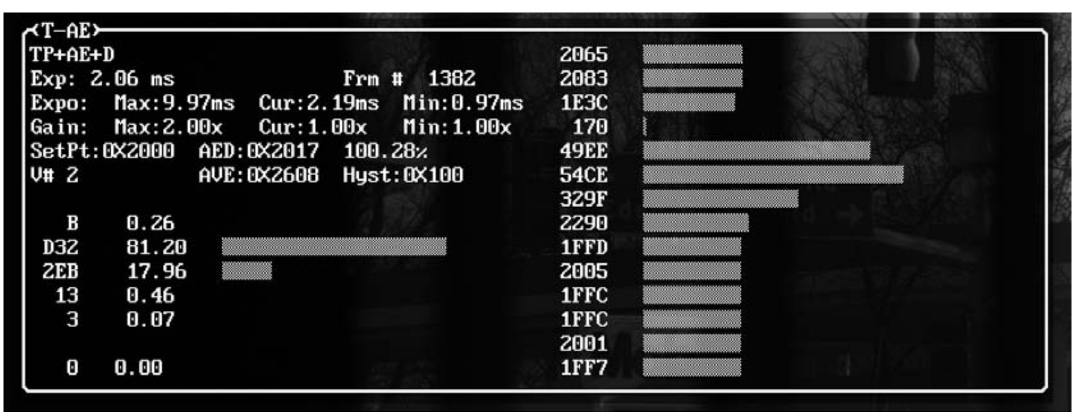


On Screen Text Display: Raster Size Information

On Screen Text Display: Real time frame counter and exposure



On Screen Text Display: White Balance / GNU (0-255 range)



On Screen Text Display: Auto Exposure

On Screen Line Plot

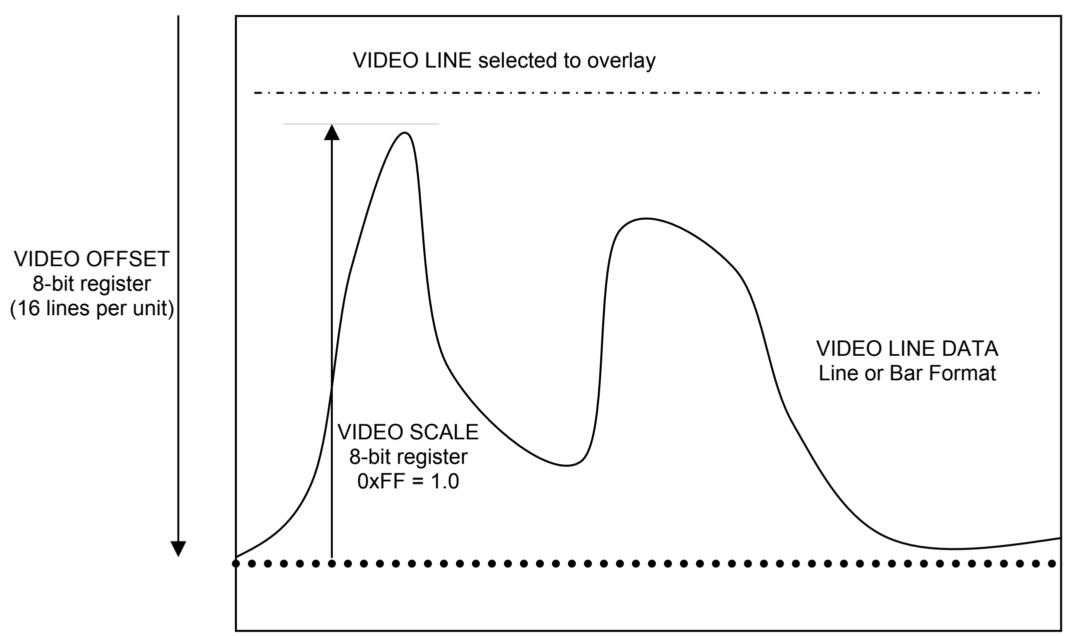
The On Screen Line Plot (OSLP) is used to overlay a graphical plot of video data onto the video image. The OSLP can be scaled and offset so that it may be placed anywhere within the video image. The OSLP Offset register (0x07) is used to select the base line = offset from the top of the image in units of 16 lines (max is 4080 lines). The OSLP Scale register reduces the line data to fit the limits of the video image. A Scale of 0xFF is unity (1.0). A Scale of 0x80 is ½ and 0x40 is ¼. The scale and offset allow 12 bit data to be drawn on a 4Kx4K image. Only the first 4096 data points of a line may be displayed, lines longer that 4096 will wrap.

Quick FAQ's:

- ►The line plot display is one frame behind it's measurement frame. This is due to the fact the the data must be measured, then stored for display on the following frame.
- ►The line plot can be scaled from 1X to 1/4096X

Serial Commands

Target	Index	Command	R/W	Description
04	11	OSD lines	W	0x0000 disable line plot 0x0001 line plot 0x0008 draw as line 0x0009 draw as filled
04	12	Line Plot Offset	R/W	
04	13	Line Plot Scale	R/W	
04	14	Line Plot Line of Interest	R/W	



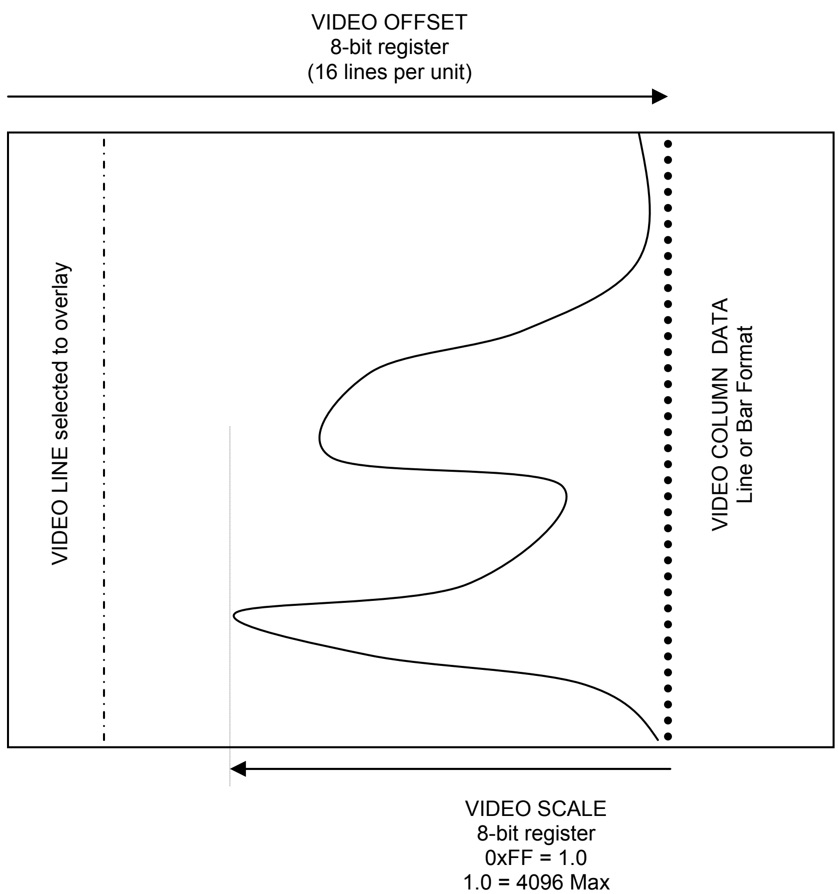
On Screen Column Plot

The On Screen Column Plot (OSCP) is used to overlay a graphical plot of video data onto the video image. The OSCP functions like the OSLP except in the vertical direction.

Quick FAQ's:
- ►The column plot display is one frame behind it's measurement frame. This is due to the fact the the data must be measured, then stored for display on the following frame.
- ►The line column can be scaled from 1X to 1/4096X: 4096 pixels to 1 pixel.

Serial Commands

Target	Index	Command	R/W	Description
04	11	OSD lines	W	0x0000 disable line plot 0x0002 column 0x0008 draw as line 0x0009 draw as filled
04	12	Line Plot Offset	R/W	
04	13	Line Plot Scale	R/W	
04	14	Line Plot Line of Interest	R/W	



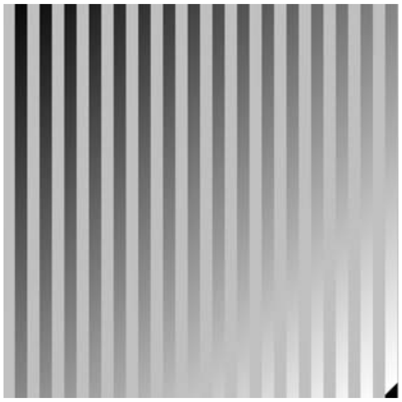
Synthetic Test Patterns

The RMV camera have two synthetic test patterns that can be used for testing the digital path and Camera Link communications.

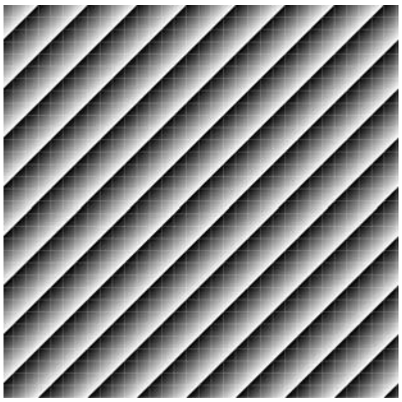
Quick FAQ's:
- ►The input test pattern can be used to test the internal data path of the RMV FPGA.
- ►The Output test pattern can be used to test the Camera Link digital communication path.

Serial Commands

Target	Index	Command	R/W	Description
04	06	Test Pattern	W	0x0000 = Normal Video 0x0001 = Input (CCD) Test Pattern 0x0002 = Output Test Pattern



Input (CCD) Test Pattern



Output Test Pattern

Detector Window Display

The RMV image detectors analyze image information within specific areas called “windows”. These windows can be displayed as an overlay on the image for reference..

Quick FAQ’s:
► Some windows are in the non visible regions of the sensor. You can see these regions by changing the LVAL/FVAL start and stop registers.

Serial Commands

Target	Index	Command	R/W	Description
04	19	Show Detectors	W	0x0000 = Tap A Crack 0x0001 = Tap B Crack 0x0002 = AE Window 0x0003 = AF Window 0x0004 = SNR Left 0x0005 = SNR Right 0x0007 = AF data 0x0008 = AF data window/screen 0x0009 = disable 0x000A = Blooming

RMV-4020 Auto Exposure Detector

Histogram Plot

The On Screen Line Plot (OSLP) can also be used to display a Histogram plot of the image data

The histogram in sampled within the entire image area with a circuit that measures the top 9 bits of image data. This results in a histogram of 512 points for the full image data range.

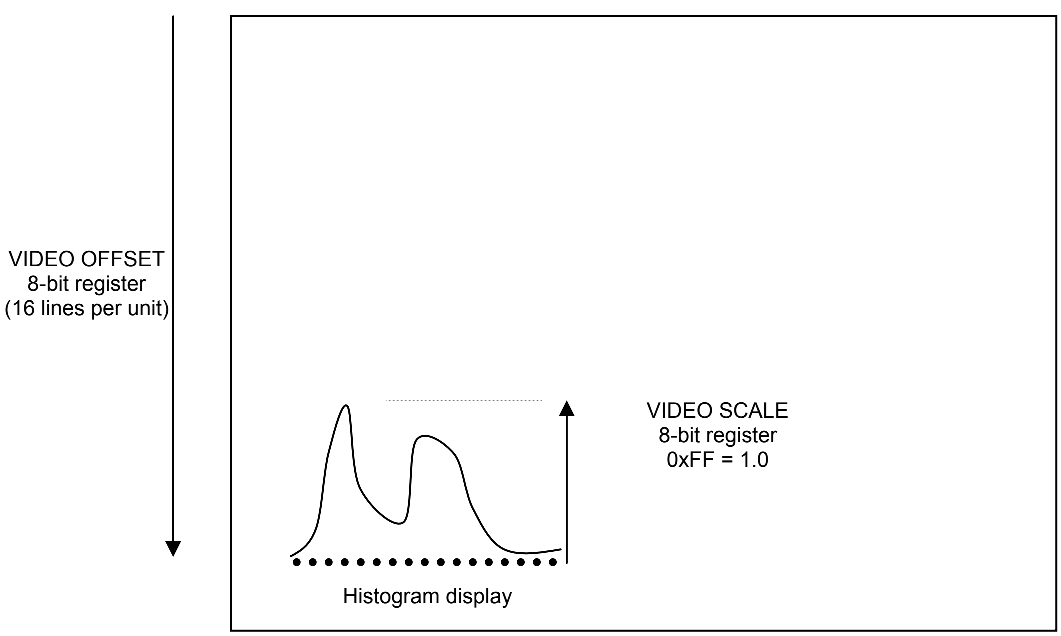
The histogram circuit can be set to measure the top or bottom 512 counts using the histogram zoom function.

Quick FAQ's:

- ►The histogram plot display is one frame behind it's measurement frame. This is due to the fact the the data must be measured, then stored for display on the following frame.
- ►The histogram plot can be scaled from 1X to 1/4096X

Serial Commands

Target	Index	Command	R/W	Description
04	11	OSD histogram line plot	W	0x0000 Disable plots 0x000C Enable Histogram display 0x000D Histogram Zoom low 512 0x000E Histogram Zoom high 512
04	12	Plot Offset	R/W	
04	13	Plot Scale	R/W	



Chapter 8: Camera Link

Rugged Machine Vision

For Gigabit Ethernet information, consult the Pleora software manual www.pleora.com

Overview

Camera Link is a communication interface for visual applications that use digital imaging. The Camera Link (CL) interface is built upon the National Semiconductor channel link technology and specifies how image data is formatted and transferred. Channel Link consists of a driver and a receiver pair. The driver accepts 28 single ended data signals and a single ended clock. The data is serialized 7:1 and the four data streams and a dedicated clock are transmitted over five LVDS pairs. The received accepts the four data streams and the clock, decodes the data, and drives the 28 bits of data to capture circuit.

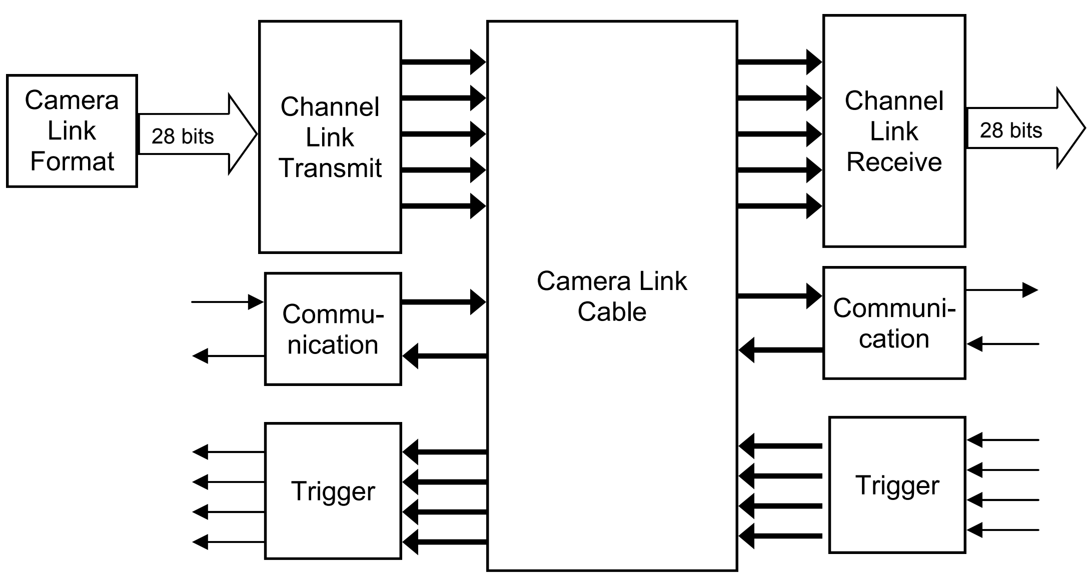
Image data and image enables are transmitted on the Camera Link bus.
The four Enable signals are:
- FVAL: Frame Valid is defined HIGH for valid lines
- LVAL: Line Valid is defined HIGH for valid pixels
- DVAL: Data Valid is defined HIGH for valid data.
- SPARE: undefined, for future use.

Four LVDS pairs are reserved for general purpose camera control. They are defined as camera inputs and frame grabber outputs. The signals are CC1, CC2, CC3, CC4. The RMV uses CC1 as the trigger source.

The Camera Link interface has three configurations. The naming conventions for the three configurations are:

Base:	Single Channel Link chip, single cable connector.
Medium:	Two Channel Link chips, two cable connectors.
Full:	Three Channel Link chips, two cable connectors.

The RMV is a base Cameral Link configuration.



Camera Link Cable Connections and Data Path

Pixel Format

The RMV samples the sensor with 12 bit precision and processes the data throughout the FPGA at 12 bits. During the data format stage the 12 bit image data can be down sampled to 10 or 8 bits. In addition the bottom 8 bit data can be output as the top 8 (msb) of the 12 bit image sample.

Quick FAQ's:
- ►Bottom 8 is very useful for evaluating camera noise
- ►Truesense Imaging sensors rated at 60dB SNR have about 10 clean bits (dynamic range).
- ►8 Bit pixel data is packed in single bytes and thus requires 1/2 the system bandwidth that the 10 and 12 bit formats require.

Serial Commands

Target	Index	Command	R/W	Description
04	0d	Bit Width	W	0x0000 = 12 bit mode 0x0001 = 10 bit mode 0x0002 = 8 bit mode 0x0003 = Bottom 8 bits (as Msb)

Sensor ADC pixel sample to Camera Link mapping

ADC bits	12 bit CL	10 bit CL	8 bit CL
11	11>11	11>9	11>7
10	10>10	10>8	10>6
9	9>9	9>7	9>5
8	8>8	8>6	8>4
7	7>7	7>5	7>3
6	6>6	6>4	6>2
5	5>5	5>3	5>1
4	4>4	4>2	4>0
3	3>3	3>1	
2	2>2	2>0	
1	1>1		
0	0>0		

8.2 Camera Link Channel Format

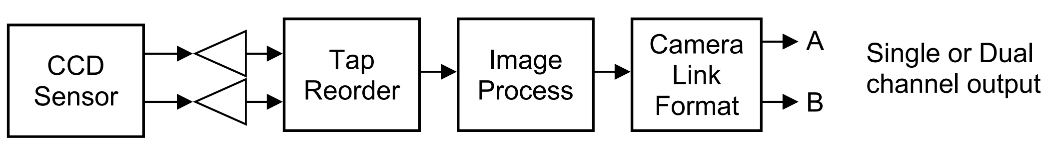
The Camera Link base mode, used on the RMV, can transfer pixel data in 8, 10, 12 bit depths and in one or two channels. Two channel mode allows for a transfer clock frequency 1/2 of the single channel mode. Because two channel mode outputs two pixels per clock the DVAL signal does cannot correctly specify valid data in all modes.

For example when binning the image the DVAL signal is used to validate the summed pixel data. In two channel mode the DVAL signal cannot specify which of the two channels has valid or invalid data. Thus single channel mode is preferred.

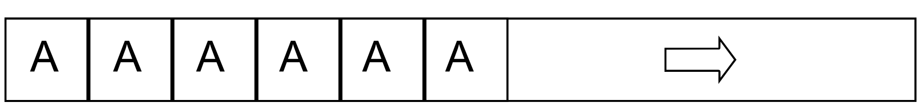
Quick FAQ's:
- Don't confuse Single/Dual Channel with Single/Dual CCD tap modes.
- Single channel output requires a pixel clock of twice the frequency of the dual channel mode.
- Some PCI Camera Link cards have a maximum pixel clock frequency of 66Mhz. With an RMV camera operating in two tap mode at 40Mhz the pixel rate is 80Mhz, greater than the card can handle. The camera must be operated in dual channel mode with these cards.
- DVAL = Data VALid: This Camera Link signal indicates when pixel data is valid with a clock.
- LVAL = Line VALid: This Camera Link signal indicates when pixel data is valid with a line.
- FVAL = Frame VALid: This Camera Link signal indicates when line data is valid with a Frame.
- In two channel mode the two channels can be swapped. This feature allows the camera to adapt to the capture device.

Serial Commands

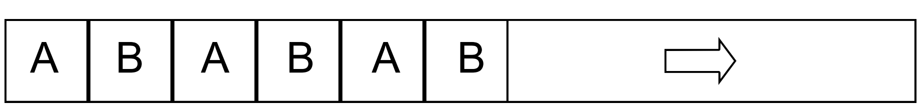
Target	Index	Command	R/W	Description
04	01	Channels	W	0x0000 = Single channel output 0x0001 = Dual channel output 0x0002 = Normal order dual channel 0x0003 = Swapped order dual channel



Pixel Sample to Camera Link data path



Single channel output



Dual channel output

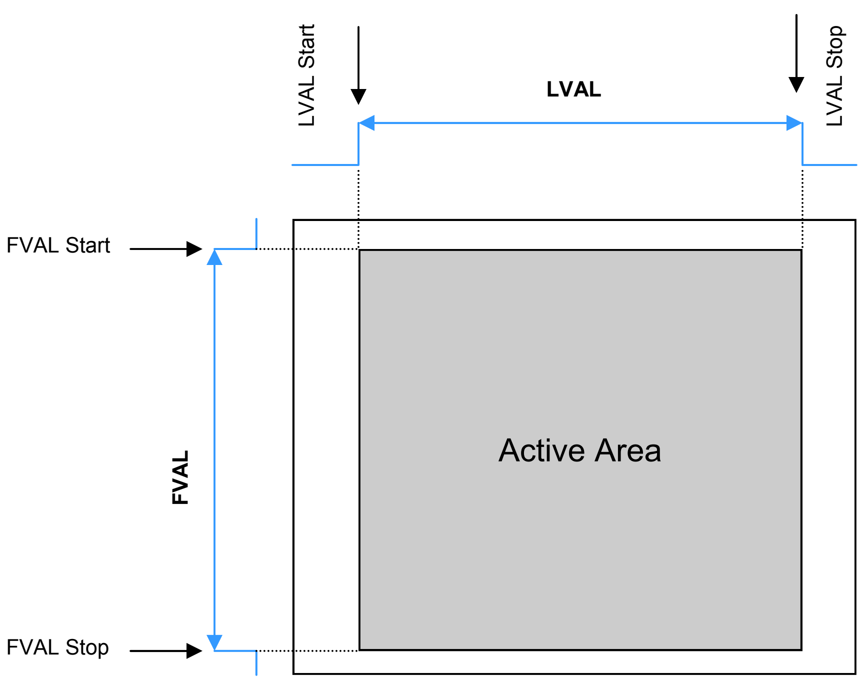
Camera Link Valids

The RMV samples and processes the entire area of the image sensor. In the standard operating mode only the active image area is output on the camera link as valid data. The LVAL/FVAL signals, which define the valid pixel data, can be programmed to output any part of the image including the optical black clamping areas. FVAL start/stop are specified in lines. LVAL start is in pixels plus the overhead of the CCD vertical clocks. LVAL stop is specified as the same as LVAL start with the exception of its maximum value is 1. VALID starts and stop changes are not stored on system save and must be reprogrammed each time they are

Quick FAQ's:
- ►LVAL = Line VALid: This Camera Link signal indicates when pixel data is valid with a line.
- ►FVAL = Frame VALid: This Camera Link signal indicates when line data is valid with a Frame.
- ►LVAL start and stop define a lines active pixels and are in some weird internal FPGA counting unit.
- ►FVAL start and stop define a frames active lines and are directly related to the sensor design.
- ►The SNR detectors operate on the optical black areas of the sensor and you must change LVAL start and stop to display them.

Serial Commands

Target	Index	Command	R/W	Description
04	1b	System Registers	R	0x0008 = LVAL Start 0x0009 = LVAL Stop 0x000a = FVAL Start 0x000b = FVAL Stop
04	27	System Registers	W	0x0008 = LVAL Start 0x0009 = LVAL Stop 0x000a = FVAL Start 0x000b = FVAL Stop



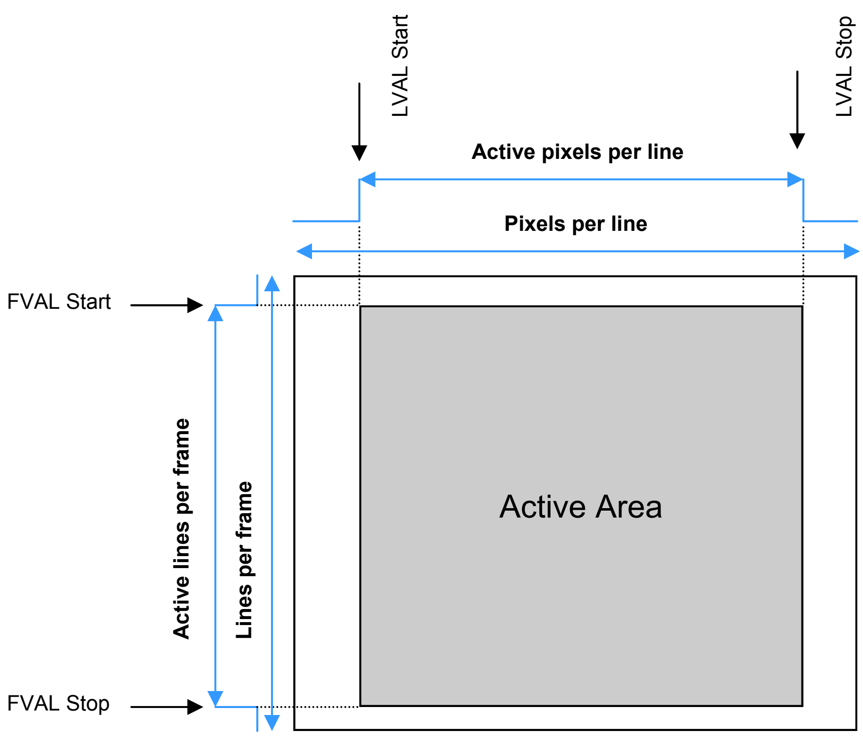
Raster and Exposure Detectors

Cameras like the RMV are very complex and can generate many different raster formats. To document all possible combinations of binning, partial scan and triggering is next to impossible. To alleviate this the RMV incorporates a set of raster detectors that measure the video image raster as sent to the capture device. These measured values can be used to set the capture parameters. In addition to the raster size an exposure detector is included. The exposure detector measures the exposure of the CCD sensor in units of the master pixel clock rate. The frame CRC is used in the built in test functions of the camera.

Quick FAQ's:
- ►Active pixels per line = LVAL active pixel count.
- ►Active lines per frame = FVAL active line count.
- ►The exposure detector counter is a 32bit integer. This gives a range of exposure from one clock period to over 2 seconds.
- ►Exposure is measured in pixel clock periods.
  A 40Mhz clock has 0.025us periods
  A 30Mhz clock has 0.033us periods
  A 20Mhz clock has 0.050us periods

Serial Commands

Target	Index	Command	R/W	Description
04	1b	System Registers	R	0x0000 = Pixels per line 0x0001 = Active pixels per line 0x0002 = Lines per frame 0x0003 = Active lines per frame 0x0012 = Exposure counter low word 0x0013 = Exposure counter high word 0x0014 = Frame CRC



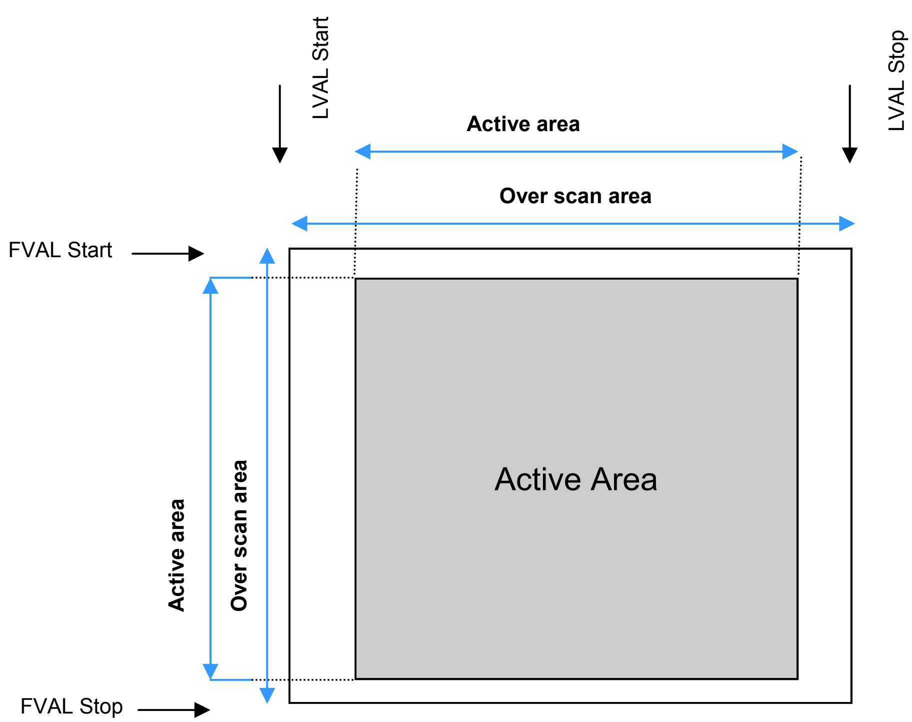
Over Scan Mode

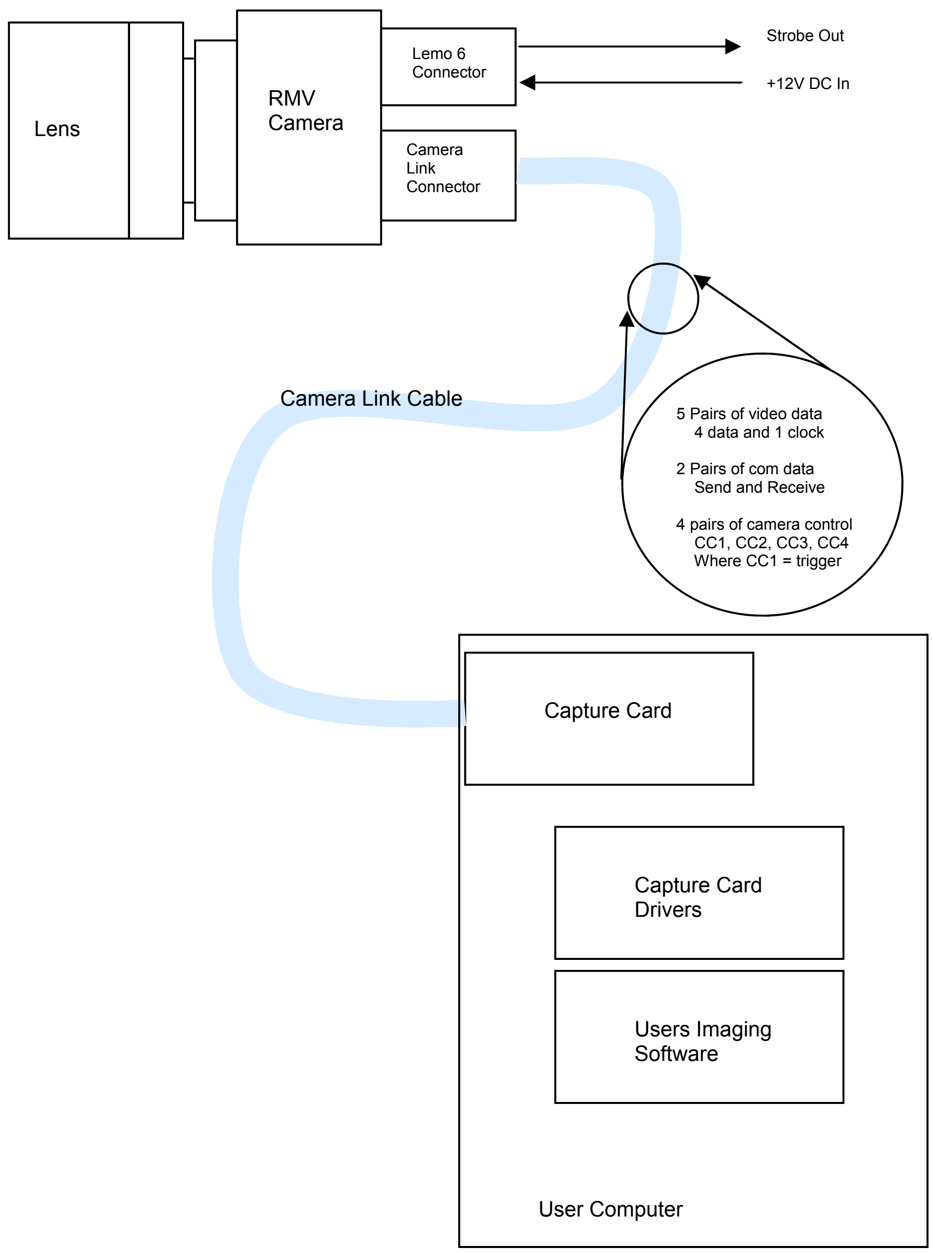
A special mode is available that allows all of the pixels of the sensor to be output in an over scan mode. This mode allows the user to capture the special performance measuring and optical black pixels from the sensor. In over scan mode the LVAL and FVAL are modified to allow the capture device to sample the extra pixels.

Quick FAQ's:
- ►CCD sensors have special pixels that are used to measure performance and optical black.
- ►Optical black pixels are shielded from light by metal that covers the pixels.
- ►Most cameras only output the active pixels of the sensor.
- ►Over scan mode allows the user to measure the performance of all pixels on the sensor.

Serial Commands

Target	Index	Command	R/W	Description
04	08	Over scan mode	W	0x0000 = Disable over scan mode 0x0001 = Enable over scan mode




Lens
RMV Camera
Lemo 6 Connector
Strobe Out
+12V DC In
Camera Link Connector
Camera Link Cable
5 Pairs of video data
4 data and 1 clock
2 Pairs of com data
Send and Receive
4 pairs of camera control
CC1, CC2, CC3, CC4
Where CC1 = trigger
Capture Card
Capture Card Drivers
Users Imaging Software
User Computer

This section of Frequently Asked Questions is intended to help the first time user to setup and control the camera.

FAQ# 1: *How do I change camera settings?*
See Section 3 for specific camera mode commands.

FAQ# 2: *How do I set the camera's electronic exposure?*
See Section 4 for specifics.

FAQ# 3: *How does the dual tap mode work?*

The CCD sensor used in the RMV is a dual tap device. To improve performance the sensor incorporates two read taps, one at the left and one at the right side of the sensor. The camera changes its internal clocking depending on the tap mode. The data is clocked to the appropriate tap and read into the camera ADC's.

FAQ# 4: *How do I set the tap mode (single and dual)?*
See Section 3 command 04 00 for specifics.

FAQ# 5: *How do I set the ADC pre-gain?*
See Section 4 command 04 06 for specifics.

FAQ# 6: *What camera link data formats are used?*

The RMV cameras with Camera Link use the base configuration of the CL spec. The RMV uses the 1 or 2 tap, 8,10, or 12 bits per tap camera link setting. The RMV cameras has features that allow the user view the bottom 8 bits of the 12 bit pixel data and to swap channels.

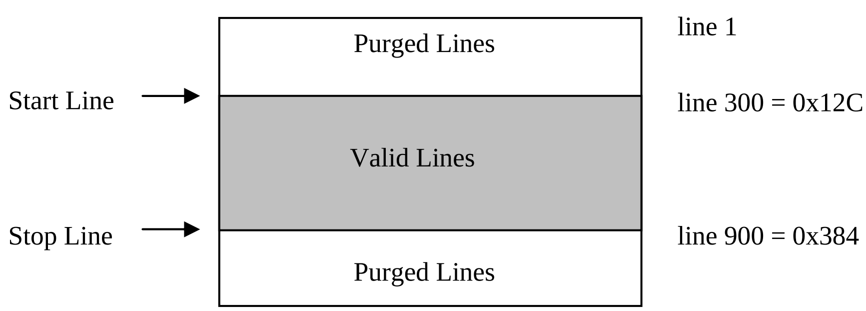
FAQ# 7: *What is the test pattern?*

The RMV cameras incorporate a two digital test patterns. One the test pattern appears as a gray ramp with a white grid overlaid on it. The other test pattern is a gray ramp only. The test pattern is very useful in hunting down problems with cables and captures cards.
See Section 7 for specifics.

Color balancing is adjusted by changing the Green #1, Red, Blue and Green # 2 gains in each Tap.

FAQ# 8: *What is partial scan and how do I use it ?*

Partial Scan (PS) is special readout mode that allows the camera to read a portion of the image while purging the remaining image data. This read and purge process allows the camera to read the selected areas much faster than reading the entire image. The start line register specifies the line on which to begin image readout. The camera will purge all lines up to the start line, then begin read out of the image data. The start line must not be set to 0. The stop line register specifies the line on which to end image read out. The camera will purge all lines after the stop line and until it reaches the last line on the sensor.
See Table 1.1 command 04 09, 04 0a and 04 0b for specifics.



Note that if you are using a color Bayer pattern sensor you will need to select your start line carefully so that the color processing hardware or software receives the proper data. Note the HDTV sensor does not support partial scan.

FAQ# 9: What is binning and how do I use it?

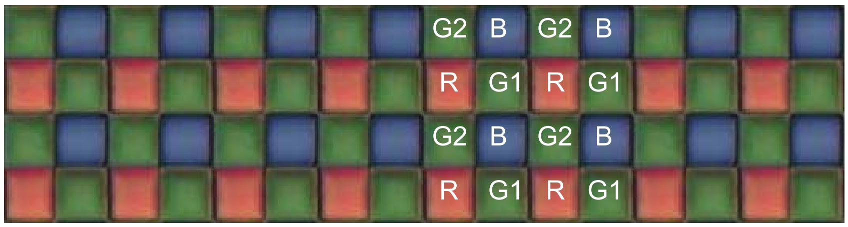
Binning is a special readout mode where the camera 'bins' or combines pixel data. The effect of binning is that the image will have lower resolution but higher SNR, and by using vertical binning the image readout speed is improved. The RMV cameras implement horizontal and vertical binning as separate controls. The horizontal binning can be independently selected to bin 1, 2, or 4 pixels. The vertical binning can be selected to 1, 2, 4, 8 or 16 lines.
See Table 1.1 command 04 05 for specifics.

FAQ# 10: *How does the trigger mode work?*

The CC1 lines on the Camera Link interface control the trigger signal. The polarity of the trigger can also be set.
See Table 1.1 command 04 03 and 04 0e for specifics.

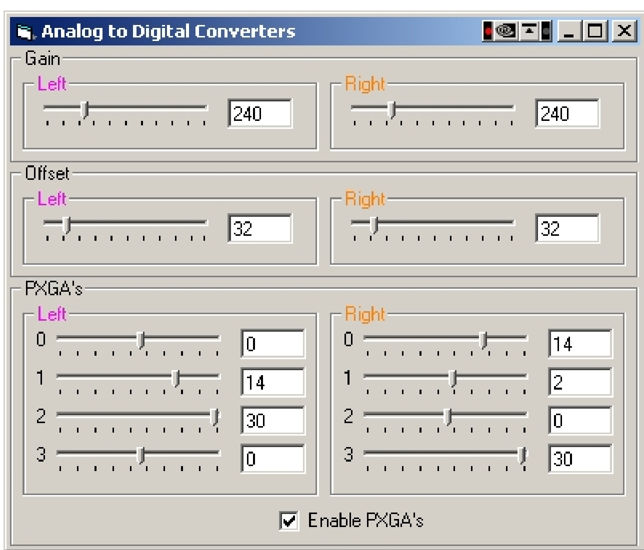
FAQ# 11: *How does the color version work?*

The color versions of the RMV cameras are the same hardware as the monochrome versions but incorporate a sensor that has a Bayer pattern. The Bayer pattern is a RGB color pattern that consists of even lines with R-G-R-G-R-G... pixel patterns and odd lines with G-B-G-B-G... pixel patterns. These colored patterns are decoded and used to generate a RGB image. Your capture card or application must process the Bayer pattern, as the camera does not.



The Bayer Pattern

The RMV color camera contains special ADC's, which can pre-gain the Bayer pattern colors before they are converted to digital values. This allows for the maximum dynamic color range as the white balance of the camera is performed in the analog domain. The color gain registers provide an offset gain that increase or decrease the gain from the main VGA amplifier. Consult the Analog Devices AD9845A data sheet for more information at www.analog.com. Note that there is a gain register for each of the two Green pixels in the Bayer pattern. You must set both green gains to achieve correct white balance. In practice the green color filters have slightly different responses must be set correctly to eliminate color pattern problems. The color steering mode has no useful effect on a monochrome camera, as it is not supported in the camera hardware.



RMV ADC Control with PxGA

PxGA Example Color Control

Left Tap	Right Tap
Green 1	Red
Red	Green 1
Blue	Green 2
Green 2	Blue

The dialog box shows a typical setup for the PxGA control for a average room white balance. Reds are gained to 14 and Blues are Gained to 30. Usually one of the Greens will need some gain as well. Settings are dependant on lighting and color temperature.

FAQ# 12: *Why does H binning not shrink the line size?*

The Horizontal binning modes require the use of the Data Valid (DVAL) signal on the Camera Link bus. Some capture cards require you to explicitly turn on the DVAL feature. I addition some cards require you to set the DVAL polarity and activation status (i.e. if DVAL is applied on a pixel or frame basis). Activating the DVAL signal will then result in the correct H line size.

FAQ# 13: How do I calculate Well depth ?

The well depth for a given sensor is list in the sensors data sheet. Maximum Well depth of an image can be calculated if we know the ADC gain and the number of electrons per micro volt of the sensor output amplifier. For the Truesense Imaging sensors we have:

The 12 bit ADC has a 1vpp input with a 2V ADC stage This requires a 6dB gain to match the input to the ADC. So at 6dB (gain 2X) a 1vpp input gives 1V/(2^12 counts) or 244.14 uV/count.

From calculated gain in dB we get a gain factor:
gain factor = 10 ^ (gaindB/20)

Sensor	Pixel Size	Saturation Signal	Sensitivity
KAI-1010	**9.0µm x 9.0µm**	**50,000e**	**12 µV/e**
KAI-2020	**7.4µm x 7.4µm**	**40,000e**	**30 µV/e**
KAI-4021	**7.4µm x 7.4µm**	**40,000e**	**31 µV/e**
KAI-04022	**7.4µm x 7.4µm**	**40,000e**	**33 µV/e**
KAI-08050	**5.5µm x 5.5µm**	**20,000e**	**34 µV/e**
KAI-11002	**9.0µm x 9.0µm**	**60,000e**	**13 µV/e**
KAI-16000	**7.4µm x 7.4µm**	**30,000e**	**30 µV/e**
KAI-29050	**5.5µm x 5.5µm**	**20,000e**	**34 µV/e**

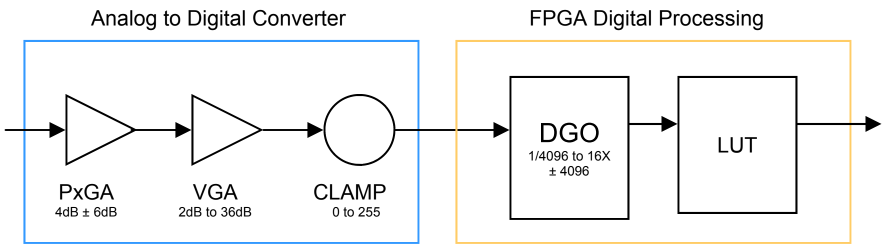
Thus for a KAI-4021 with 31uV/e we get
1 count = (244 x 2) / (gain factor * 32) electrons

From the ADC max count we can calculate well depth !

FAQ# 14: What gains and offsets does the camera have ?

The RMV has several stages of gain and offset that are applied to the image data.

1) PxGA: 4dB ± 6dB. Analog gain applied to each of the four Bayer pattern colors.
   Red, Red-Green, Blue, Blue-Green. Applied for each tap independently.
2) VGA: 2dB to 36dB: Analog gain applied to all pixels for each tap.
   CLAMP: 0 to 255 applied as analog offset per line in DN increments.
3) Digital Gain 1/4095 to 16X in 1/4096 steps for each tap.
   Digital Offset: -4095 to 4095 in DN increments.
4) Flat Field Gain: 0.5X to 1.5X in 1/1024 steps for each pixel independently.
   Flat Field Offset: -126 to 126 in DN increments for each pixel.



RMV Image Data Gain and Offsets

In this release of the RMV (4) the concept of gain has changed to a fixed analog gain and a variable digital gain. This allows the analog section to be set to an optimum setting for noise and linearity and allow the flexibility of a continuously variable user gain.

FAQ# 15: What is the difference between single tap and single channel mode ?

The single tap mode refers to the CCD sensor operation. The Truesense Imaging CCD sensors can be clocked in one or two tap modes. The two tap mode will read the image from the sensor twice as fast as the single tap mode. The RMV reorders the two tap image data with the TRO circuit. The internal reordered data is then processed as a single image raster.

The single channel mode refers to the Camera Link operation. The camera link base mode data transfer can occur in one or two channels, each with 8/10/12 bits per channel. Another way to describe the channels is to refer to them as pixels. Thus for each clock cycle, of the camera link transport, either a single pixel or two pixels can be transferred. The two channel mode can transfer twice the data for a given clock rate and thus reduces the pixel clock and camera power.

FAQ# 16: How do I see the optical black pixels?

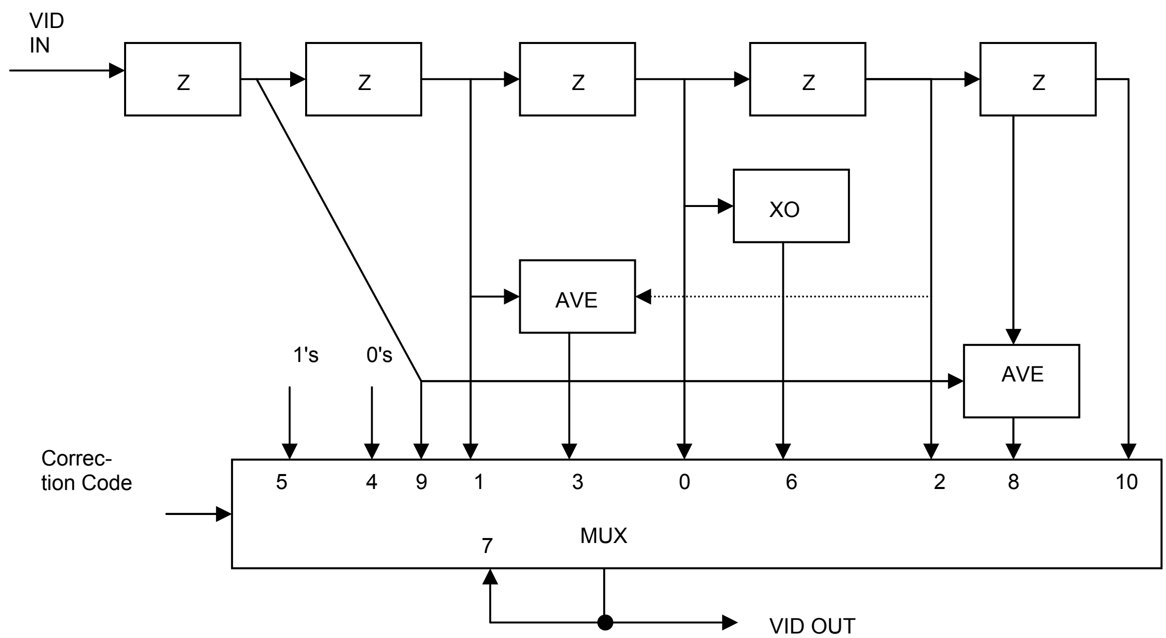
The RMV has a new mode called overscan that is used to view the optical black pixels.

FAQ# 17: I have a third party camera link cable that does not always work !

Run into the woods screaming! Seriously, the camera link specification is very specific about cable design. We have found several cables manufactured offshore that do not meet the camera link maximum cable length and data rates. Please do not use unauthorized camera link cables.

FAQ# 18: How does the Pixel Defect Mapper work ?

The pixel defect mapper calculates all possible pixel corrections in real time using the circuit block diagram below. When the address of a pixel or column is matched in the PDM table the correction code is used to determine which of the possible correction values are used. This allows the PDM to operate and a maximum of 80 Mhz.



FAQ# 19: What IR/UV filter should I use with the color sensors ?

The color Bayer pattern sensors require the use of a UV/IR filter to obtain the best response when processing image data. The filter that we use is:

B&W UV-IR CUT part number 486 with a 52mm thread.

It can be purchased from:

www.edmundoptics.com part numbers NT54-750

http://www.edmundoptics.com/onlinecatalog/displayproduct.cfm?productID=1524

Other thread sizes are available

illunis has developed a birefingent blur filter for the KAI-29050. Call for details.

illunis

FAQ# 20: Basic examples of command sequences.

Example: Single Tap 8 bit triggered

{w0403000000} Free Run Mode (Set first so camera frames)
{w04020001ff} Line Clamp mode (a must for triggering)
{w040d0002fe} 8 bit camera link readout mode
{w0400000000} Single tap mode (forces single channel camera link)
{w02042222bc} Programmed exposure time
{w04030001ff} Triggered Program Exposure mode

Example: Dual tap 12 bit partial scan of 256 lines

{w0403000000} Free Run Mode
{w04020001ff} Line Clamp mode (a must for partial scan and binning)
{w040d000000} 12 bit camera link readout mode
{w04000001ff} Dual tap, interleaved data mode (forces dual channel CL)
{w040a0100ff} Partial Scan start line
{w040a0200fe} Partial Scan stop line
{w040480037d} Enable Partial Scan

Example: Single tap 12 bit 8x4 binning

{w0403000000} Free Run Mode
{w04020001ff} Line Clamp mode (a must for partial scan and binning)
{w040d000000} 12 bit camera link readout mode
{w0400000000} Single tap mode (forces single channel camera link)
{w042b0008f8} Horizontal Binning of 8X (Free run mode)
{w042a0004fc} Vertical binning of 4X (Free run mode)
{w0404000000} Enable binning in trigger and free run mode

Example: Free Run Auto Exposure

{w0403000000} Free Run Mode (Set first so camera frames)
{w040d000000} 12 bit camera link readout mode
{w04000001ff} Dual tap, interleaved data mode (forces dual channel CL)
{w041e1000f0} AE set point to 0x1000 (Depends on sensor and lens)
{w041d0001ff} Activate Auto Exposure

Example: Triggered Auto Exposure, camera to output only triggered frames.
Free run in 4x4 binning for faster AE performance

In this example the camera will free run in a 4x4 binned mode.
By using the Async reset feature we can make the camera respond to a trigger and output a full (non binned) image.
In the free run mode the auto exposure will track and adjust the image brightness.
The auto exposure algorithm will continuously update TPD so that a trigger assertion will cause a triggered readout of a full frame with the correct exposure.
The disable Runs Valid will disable the LVAL/FVAL signals in free run and a enable the valid signals only for the triggered image readout.

{w0403000000} Free Run Mode
{w04020001ff} Line Clamp mode (a must for partial scan and binning)
{w040d000000} 12 bit camera link readout mode
{w0400000000} Single tap mode (forces single channel camera link)
{w042b0004fc} Horizontal binning 4X (Free run mode)
{w042a0004fc} Vertical binning 4X (Free run mode)
{w0404800080} Enable binning in free run mode (Not Trigger)
{w04030008f8} Disable Runs Valid
{w04030005fb} Enable Async Reset
{w04030001ff} Triggered Program Exposure mode
{w041e1000f0} AE set point to 0x1000 (Depends on sensor and lens)
{w041d0001ff} Activate Auto Exposure

FAQ# 21: How should I power the cameras ?

The RMV cameras require a constant power supply at a voltage of 12 volts and a current of from 200mA to as much as 1000mA. The start up of the camera's on board power supplies require more than the steady state current, as much as three times as much. The input power should be clean with no more than 500mV of ripple at full load.

FAQ# 22: What is DATA VALID or DVAL ?

The camera link specification calls for cameras to provide the following signals

24 data
LVAL = Line Valid (valid pixels within a line)
FVAL = Frame Valid (valid lines within a frame)
DVAL = Data Valid
Data Clock (Minimum of 20Mhz)

Data valid is a sent from the camera to the capture card to indicate valid data. It is used in the RMV cameras during horizontal binning to indicate valid pixels. The capture card should be set to use DVAL and only for active pixels.

FAQ# 23: Checksum Calculation

The checksum is used in two different implementations; data only (default) and command and data. Consider the command packet: {wCCIIDDDDSS} where CC = command, II = Index, DDDD = data, and SS = checksum. For the data only we use a C function as follows;

```
UINT8   CheckSum( UINT16 twobytes )
{
UINT8 checksum,byte0,byte1;

        byte0 = twobytes & 0x00ff;
        byte1 = (twobytes >> 8) & 0x00ff;

        checksum = byte0 + byte1;
        checksum = 256 - checksum;

        return(checksum);
}
```

The checksum for the data only is:
SS = CheckSum(DDDD);

For the checksum of the command and data we use:
SS = CheckSum(DDDD) + CheckSum(CCII);

Where DDDD is 4 digit hex. and CCII is a concatenated 4 digit hex number.

What if I have problems?

Please call or email illunis directly.
Our phone number is (952) 975-9203
Our email is info@illunis.com. Ask for Dave

Suggestions Wanted !!!

Send any comments to dave@illunis.com We want to help with any problems.

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